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Literature Review

Mangrove Feedstock Potentials for Ruminant

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Abstract: Mangrove forests play an important role in maintaining the health and productivity of coastal ecosystems, as well as providing valuable services such as sequestering atmospheric carbon (blue carbon storage), shoreline protection, protection from natural disasters (floods, storms, tsunamis, and coastal erosion), buffering salinity changes, food supply, provision of feed resources, fuel, building materials, protection of diversity including habitat for local flora and fauna. Mangrove forests provide livelihood opportunities for coastal communities through aquaculture, livestock feed, and ecotourism. The study aims to determine the potential and species of mangroves that can be utilized as a source of ruminant feed in East Kalimantan province by using an exploratory approach through literature studies and secondary data from Statistics Indonesia. The data was then identified and analyzed through qualitative description. The abundance of existing mangroves needs to be optimally utilized and explored as a source of local feed. Optimization of feedstock can be a strategy for realizing sustainability, feasibility, and production efficiency so that the utilization of local feedstocks can reduce feed costs and increase production efficiency which will provide high benefits for farmers. Ruminant rearing patterns with intensive systems and feed fulfillment with cut and carry techniques can be a solution to utilize mangrove biomass as an alternative feedstock. Ruminant development in mangrove forest areas is expected to be realized with the support of mangrove leaf-based livestock feed industrialization.

Keywords: Feed, Industrialization, Mangrove, Nutritions, Ruminants

Introduction

Mangroves are coastal forests that lie between land and sea in tropical and sub-tropical areas throughout the world (Alam *et al*., 2021; Akram *et al*., 2023; Elwin *et al*., 2024). Indonesia has mangrove forests which are estimated to reach 4.25 million ha or almost 30% of the world's total mangrove area and its seacoast is a habitat for ±47 mangrove species (Abdunnur, 2021). Mangrove forests represent a collection of trees and shrubs that can thrive in a dynamic ecological environment with varying soil oxygen concentrations and saltwater input (Akram *et al*., 2023). Its biodiversity makes mangrove forests known as rainforests of the seas (Akram *et al*., 2023), tidal forests, coastal woodlands, and forests (Kusmana and Sukardjo, 2016). The distribution of mangrove forests is limited from tropical areas to 32°N and 38°S latitude (Kusmana and Sukardjo, 2016). Mangrove ecosystems have various benefits, physically the function of mangrove forests is as disaster mitigation such as reducing waves and storms for the area behind them, retaining mud, preventing seawater intrusion onto land and protecting beaches from abrasion, tidal waves, tsunamis (Fithor *et al*., 2019; Ahouangan *et al*., 2022; Sunkur *et al*., 2023). Other functions are as a habitat for flora and fauna (Akram *et al*., 2023) as well as providing a food source for various livestock commodities that live in water (fish, shrimp, crabs, shellfish) (Ickowitz *et al*., 2023) and on land including ruminants (cattle, buffalo, goats and sheep) (Kusmana and Sukardjo, 2016; Zuhri *et al*., 2022).

The mangrove forest in East Kalimantan province covers an area of 181,871 ha (Abdunnur, 2020). The

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existing abundance of mangroves needs to be utilized optimally and explored as a source of feed by livestock breeders in coastal areas, considering the important role of feed in the development of livestock commodities in a region. Feed in ruminant production has an important role, especially in supporting productivity (Mayulu and Suhardi, 2015), and has the largest proportion of all production costs, reaching 70-80% (Mayulu *et al*., 2021). Utilization of plant biomass can provide a good opportunity to supply feed at a lower price (Mayulu and Suhardi, 2015), and the use of mangroves as feed ingredients by coastal communities can be an alternative to meet ruminant feed needs where it is expected that optimal productivity can be achieved in the context of meat self-sufficiency. The utilization of mangroves as ruminant feed needs to be explored and studied deeper, which has become the background of this research. We aimed to determine the potential of mangroves as an alternative feedstock for ruminants in East Kalimantan province.

Research Methodology

We used an exploratory approach using literature studies and secondary data from Statistics Indonesia. The obtained data was then identified and analyzed descriptive qualitatively. Research related to the exploration of mangrove potency as feedstock for ruminants was carried out through the following stages (Fig. 1).

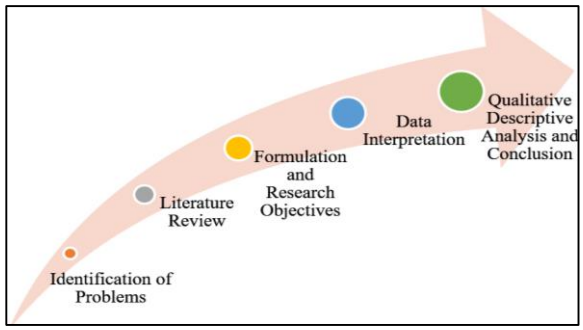

Fig. 1: Research stages

Discussion

Mangrove Characteristic

Linguistically, mangrove comes from a combination of the words mangue (Portuguese) which means plant, and grove (English) which means shrub. Mangroves can be defined as any species or communities of plant species that can live in environments with high salt levels or salt water (Saline) (Abdunnur, 2020). Mangroves include woody trees and shrubs that grow at the interface between land and sea along tropical and subtropical coasts (Adams and Rajkaran, 2020; Akram *et al*., 2023). Mangroves can grow optimally in an average temperature range of 5-20°C and are tolerant to various weather conditions (Adams and Rajkaran, 2020).

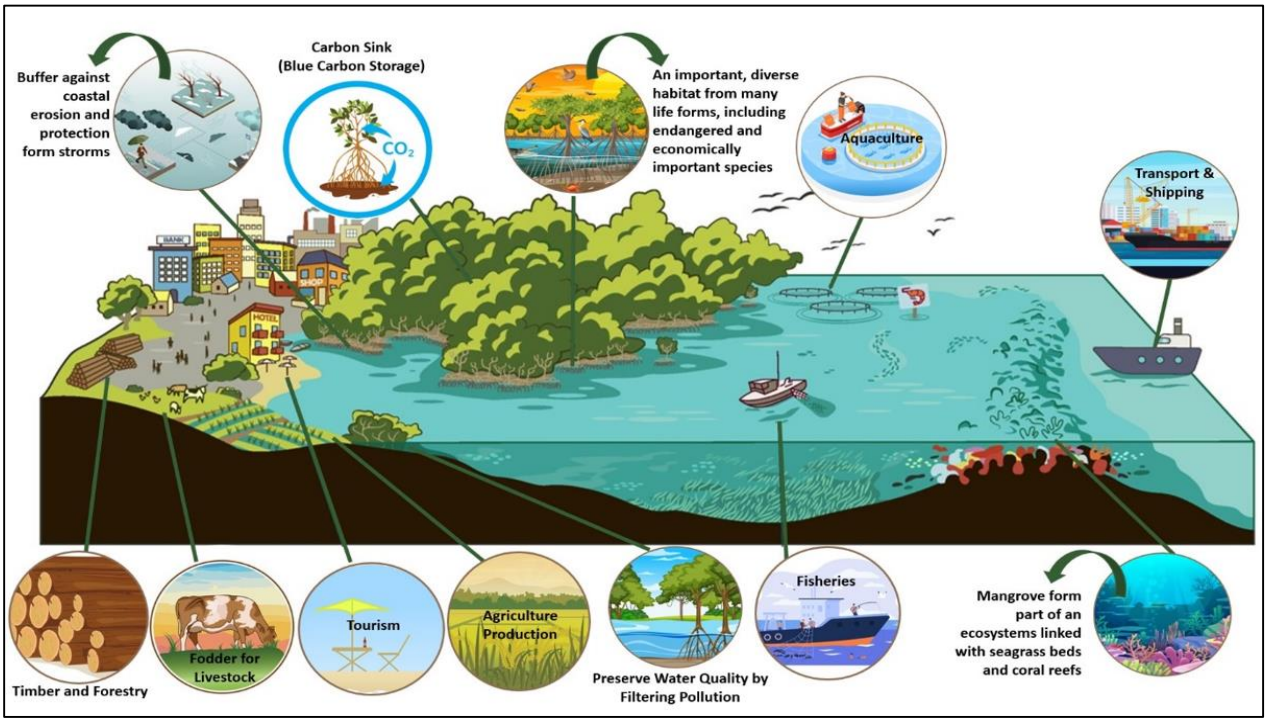

Fig. 2: Mangrove ecosystem function and services (reconstructed from Akram *et al*., 2023)

Mangrove forests play an important role in maintaining the health and productivity of coastal ecosystems (Akram *et al*., 2023) and provide valuable ecosystem services (Fig. 2). such as absorbing atmospheric carbon (blue carbon sink), protecting coastlines, protecting from natural disasters (floods, storms, tsunamis and coastal erosion), preventing changes in salinity, providing food, providing food resources, fuel, building materials, protecting diversity (Ahouangan *et al*., 2022; Damastuti *et al*., 2022; Asante *et al*., 2023) including habitat for local flora and fauna (Akram *et al*., 2023). Mangrove forests provide livelihood opportunities for coastal communities through fish cultivation, animal feed, and ecotourism (Akram *et al*., 2023).

In Indonesia, mangrove forests have a more varied structure and composition when compared to other countries (Kusmana and Sukardjo, 2016) because Indonesia is located at the equator, so it has an ideal climate for mangroves to grow and develop (Sidik *et al*., 2018). Mangroves generally spread on protected beaches and river estuaries with different species composition depending on habitat conditions. The distribution of mangrove species is related to tide type, soil type, and frequency of inundation (Kusmana, 2014). The distribution of mangroves is also influenced by salinity because mangroves can only grow in certain salinity conditions, such as the *Rhizophora* stylosa species which grows optimally at a salinity of $9^0/_{00}$ and there is a decrease in biomass at a salinity above $18^0/_{00}$, while *Avicennia* spp grows optimally at a salinity of $7\text{-}14^0/_{00}$ (Abdunnur, 2020). The following is the distribution of mangrove species on several islands in Indonesia (Table 1) and the identification of mangrove species based on shape, type of roots, leaves, flowers, and fruit (Table 2).

Table 1: The distribution of mangrove species in Indonesia

No.	Species	Island						
		Java	Bali	Sumatra	Kalimantan	Sulawesi	Maluku	Papua
01	*Aegiceras corniculatum*	√	√	√	√	√	√	√
02	*Aegiceras floridum*		√			√	√	√
03	*Avicennia alba*	√	√	√	√	√	√	√
04	*Avicennia lanata*				√	√		
05	*Avicennia marina*	√	√	√	√	√	√	√
06	*Avicennia officinalis*	√	√	√	√	√	√	√
07	*Bruguiera cylindrica*	√	√	√	√	√	√	√
08	*Bruguiera gymnorrhiza*	√	√	√	√	√	√	√
09	*Bruguiera parviflora*	√	√	√	√	√	√	√
10	*Bruguiera sexangula*	√	√	√		√	√	√
11	*Ceriops decandra*	√	√	√	√	√	√	√
12	*Ceriops tagal*	√	√	√	√	√	√	√
13	*Dolichandrone spathacea*	√						
14	*Excoecaria agallocha*	√	√	√	√	√	√	√
15	*Heritiera littoralis*	√	√	√	√	√	√	√
16	*Kandelia candel*			√	√			
17	*Lumnitzera littorea*	√	√	√	√	√	√	√
18	*Lumnitzera racemosa*	√	√	√	√	√	√	√
19	*Nypa fruticans*	√	√	√	√	√	√	√
20	*Osbornea octodonta*	√	√			√	√	√
21	*Phoenix paludosa*			√				
22	*Pemphis acidula*	√	√					√
23	*Rhizophora apiculata*	√	√	√	√	√	√	√
24	*Rhizophora lamarckii*		√	√			√	√
25	*Rhizophora mucronata*	√	√	√	√	√	√	√
26	*Rhizophora stylosa*	√	√	√	√	√	√	√
27	*Scyphiphora hydrophyllacea*	√	√	√	√	√	√	√
28	*Sonneratia alba*	√	√	√	√	√	√	√
29	*Sonneratia caseolaris*	√	√	√	√	√	√	√
30	*Sonneratia ovata*	√		√	√	√	√	√
31	*Xylocarpus granatum*	√	√	√	√	√	√	√
32	*Xylocarpus moluccensis*	√	√	√	√	√	√	√
33	*Xylocarpus rumphii*	√	√				√	√

Table 2: Mangrove species identification based on shape, root type, leaf, flower, and fruit

No.	Species	Mangrove species identification																						
		Plant form						Root types				Roots are unclear	Leaf				Flower				Fruit			
		Tree	Shrub	Vine	Fern/Palm	Herb/Grass	Stilt-root	Pneumatophore	Knee-root	Plank-root	But-ress		Simple	Compound	Opposite	Alternate	Terminal	Axillary	Single	Cylindrical	Round	Bean-like		etc
01	*Aegiceras corniculatum*		√									√	√		√		√			√				
02	*Aegiceras floridum*		√									√	√		√		√			√				
03	*Avicennia alba*	√						√					√		√		√					√		
04	*Avicennia lanata*	√						√					√		√		√					√		
05	*Avicennia marina*	√						√					√		√		√					√		
06	*Avicennia officinalis*	√						√					√		√		√					√		
07	*Bruguiera cylindrica*	√							√				√		√			√		√				
08	*Bruguiera gymnorrhiza*	√							√		√		√		√			√	√	√				
09	*Bruguiera parviflora*	√							√				√		√			√	√	√				
10	*Bruguiera sexangula*	√							√		√		√		√			√	√	√				
11	*Ceriops decandra*	√									√		√		√			√	√	√				
12	*Ceriops tagal*	√									√		√		√			√		√				
13	*Dolichandrone spathacea*	√										√		√			√			√				
14	*Excoecaria agallocha*	√									√		√			√		√				√		
15	*Heritiera littoralis*	√										√	√			√		√				√		
16	*Kandelia candel*	√										√	√		√					√				
17	*Lumnitzera littorea*	√									√		√			√	√							√
18	*Lumnitzera racemosa*	√										√	√			√		√			√			√
19	*Nypa fruticans*				√							√		√		√		√						
20	*Osbornea octodonta*		√									√	√		√			√						√
21	*Phoenix paludosa*	√										√		√				√				√		
22	*Pemphis acidula*		√									√	√					√						√
23	*Rhizophora apiculata*	√					√						√		√			√		√				
24	*Rhizophora lamarckii*	√					√						√		√			√		√				
25	*Rhizophora mucronata*	√					√						√		√			√		√				
26	*Rhizophora stylosa*	√					√						√		√			√		√				
27	*Scyphiphora hydrophyllacea*	√										√	√		√			√						√
28	*Sonneratia alba*	√						√					√		√		√				√			
29	*Sonneratia caseolaris*	√						√					√		√		√				√			
30	*Sonneratia ovata*	√						√					√		√		√				√			
31	*Xylocarpus granatum*	√								√	√			√		√		√			√			
32	*Xylocarpus moluccensis*	√						√			√			√		√		√			√			
33	*Xylocarpus rumphii*	√										√		√		√		√			√			

Source: Reconstruction from Kusmana (2014); Kusmana and Sukardjo (2016)

Ruminant Characteristic

Ruminants include herbivores, which based on body size are divided into two, namely large ruminants (cows, buffalo) and small ruminants (goats and sheep) (Mayulu, 2019). Ruminants have a complex digestive system and a stomach that is divided into four compartments (rumen, reticulum, omasum, abomasum) (Mayulu, 2021). The complexity of digestion supports the ability of ruminants to utilize low-quality feedstock (high crude fiber) into products of high quality and nutritional value (meat and milk) (Lunagariya *et al*., 2017; Mayulu *et al*., 2020).

Table 3: Ruminants population in East Kalimantan province year 2021-2022

Ruminant Commodity	Population (head) 2021	2022
Cattle	121,290	108,613
Buffalo	6,539	6,490
Goat	68,997	58,552
Sheep	694	642

Source: Statistics Indonesia (2024)

Ruminant capabilities need to be supported by the availability of sufficient land and feedstock, including suitable geographical conditions so that they can produce optimally. East Kalimantan province has geographical conditions (climate and land), livestock resources (Table 3), and feed, so it has the potential to become a ruminant development area (Mayulu *et al*., 2020). The following table shows the ruminant population in East Kalimantan province for 2021-2022.

The ability of ruminants to consume feed is closely related to eating behavior and this eating behavior is based on the relationship between the sensory components of feed and adaptive ability (anatomical structure of the mouth and post-remastication consequences) (Dias e Silva and Abdalla Filho, 2021). Cattle and buffalo have a good ability to adapt to limited climatic conditions, food, and water. Cattle have eating behavior by their rearing pattern (grazed or penned). Cattle which is grazed have eating behavior by their basic behavioral patterns tend to be active in looking for food and determining the type of feed to be consumed and have a long meal duration which tends to be low feeding frequency. Cattle feeding behavior includes (1) Foraging (done by walking and sniffing to find vegetation); (2) Grazing (the activity of lowering the head, bringing the mouth close to the vegetation to be eaten and opening the mouth then sticking out the tongue and wrapping the leaf with the tongue, then extending the upper jaw and pulling the leaf apart from the stem); and (3) Ruminating (starts when the cattle walks into the shade and rests by chewing feed) (Wiyono *et al*., 2022). Buffaloes have adaptability similar to cattle, but buffalo are more vulnerable to living in relatively difficult areas with limited food conditions, both in quality and quantity. Muddy and watery environments (swamps) and rivers are the best habitat for buffalo because buffalo have the habit of wallowing. The wallowing activity helps buffalo get rid of excess body heat and is an effort to protect buffalo from bites of flies and other ectoparasites (Tsiobani *et al*., 2020). Goats are a type of browse livestock that consume leaves, shrubs, vines, and old grass, while sheep and cattle can not browse. Goats have structured eating behavior, i.e., (1) Starting by smelling the food and eating it if it suits their preferences because goats can differentiate between bitter, sweet, sour, and salty and goats are more tolerant of bitter food so they often consume vines rather than grass (Silva and Addalla, 2021); (2) Grabbing the preferred food can be grass, leaves, and shrubs. Goats can eat dry roots, twigs, plant bark, and dry leaves. Goats snatch by pulling and then pushing their mouths forward-up or backwards-down and if there are leaves on tall plants, the goat will use a browsing technique. Browsing is a technique for taking food by lifting the two front legs on the stem of a plant resting on the two back legs and then extending the head to the leaves of the selected plant. Goats have thin lips and are easy to move nimbly, making it possible to snatch food that is much higher than their body; and (3) Chewing, done to reduce the size of feed particles so that they are easily digested. Goats have the same rumination activity as cattle. Rumination activity begins with expelling a bolus that is temporarily stored in the rumen to be chewed again and swallowed again. After rumination, it is usually followed by resting behavior (Setianah *et al*., 2004). Goats spend more time eating (240-540 min/day within 24 h) and less time for rumination compared to sheep (minimum 480 min/day) (Pembuyun *et al*., 2013). Goats and sheep have limited swallowing ability, both in terms of quantity and retention time of digestion in the rumen (Silva and Addalla, 2021).

Sheep begin grazing by visually assessing the pasture and tend to avoid dirty areas for grazing. Sheep can graze with a grass height of 6-8 cm with a grazing depth of 2.5-1 cm. This ability is influenced by the anatomy of the sheep's small and slightly cleft upper lip, which allows sheep to graze up to 1 cm above the ground surface (Munandar *et al*., 2022). The small lip anatomy of sheep allows sheep to take smaller bites so they can be more selective in choosing food compared to other ruminants (Silva and Addalla, 2021; Munandar *et al*., 2022). The eating behavior of sheep is influenced by rearing patterns, namely sheep that are intensively reared have higher masticatory activity because much of their time is spent on rumination activities, in contrast to sheep that are pastured which tend to spend their time (9-14 h) for grazing (Munandar *et al*., 2022).

Ruminant Feed

Ruminants need proper nutrition for growth, maintenance, and providing energy to support performance and vital functions (Mayulu, 2021) to be able to produce optimally. Important nutrients needed by ruminants include water, carbohydrates, protein, fat, vitamins, and minerals. Most of these nutritional components can be obtained from forage, although they still require supplementation from other feedstock as complements (concentrates) and feed additives if needed, especially minerals. Forage is all food ingredients derived from plants including stems and leaves which can be used by livestock to support their productivity (Mayulu, 2019). Ruminants are very dependent on forage as the main source of food, but its availability fluctuates (influenced by season) (Mayulu *et al*., 2022) and is increasingly

difficult to obtain during the dry season (Mayulu *et al*., 2023) and its low nutrition (Mwangi *et al.*, 2024), so local sources of feedstock which easily accessible to farmers, continuous availability throughout the year, does not compete with humans and able to meet livestock production and reproduction needs both in quality and quantity are needed (Wanapat and Rowlinson, 2007). Local feed is any raw material originating from local Indonesian resources that has the potential to be used as feed efficiently by ruminants either as basic feed, supplements, or components of concentrates (Mayulu *et al*., 2020).

Optimizing feed resources can be a strategy for realizing sustainability, feasibility, and production efficiency, considering that ruminant production is increasingly competitive (Goes *et al*., 2019; Halmemies-Beauchet-Filleau *et al*., 2018). Feed in ruminant production is the largest component of all production costs (Mayulu, 2021), so the use of local feedstock is expected to reduce feed costs and increase production efficiency which will provide high profits for farmers (Mayulu *et al*., 2020). Information support regarding the nutritional potential of local feedstock is very important and very necessary because it can influence the level of adoption of these feed resources by breeders and the sustainability of their use.

Prospect of Mangrove Utilization in East Kalimantan Province for Ruminant Production

In terms of ecological and economic, marine coastal areas have great potential for development. The majority of coastal communities are very dependent on mangrove ecosystems, especially for goods and services (Abdunnur, 2020). The mangrove forest area is divided into two areas based on the purpose of its use, namely as a production forest area and a protected forest (Abdunnur, 2020). Mangroves provide a source of food, wood, and medicine for coastal communities (Akram *et al*., 2023) and in many countries such as Benin, Senegal, New Zealand, and Pakistan, including Indonesia, mangrove production forest areas are used as feed source for livestock (Ahouangan *et al*., 2022). East Kalimantan province has a very extensive mangrove forest reaching 181,871 ha and the Mahakam delta area is the largest mangrove forest in East Kalimantan province, reaching 125,502 ha lies from Muara Badak, Anggana, Sanga-Sanga, Samboja to Muara Jawa sub-districts (Abdunnur, 2020). The distribution of mangrove species on Kalimantan Island is quite diverse (Table 1) which indicates the abundance of biomass produced. The position of mangrove forests between land and sea (coastal) makes these areas very vulnerable to land clearing and conversion into infrastructure enterprises, fish and shrimp cultivation ponds, settlements, salt ponds, and ruminant farms (De Lacerda *et al.*, 2019; Ferreira *et al*., 2022). Coastal areas have the potential to be used as livestock development areas based on land support, availability of feed, and human resources (breeders) (Abdunnur and Mayulu, 2021).

The utilization of mangroves as a source of ruminant feed has been carried out by some communities in coastal areas (Ahouangan *et al*., 2022). Grazing on wetlands in mangrove forests in countries like Benin is the main foraging strategy, especially during the dry season, and is an alternative to overcome the shortage of forage when the dry season arrives, so that feeding depends on the dominant mangrove species in the area (Ahouangan *et al*., 2022). The dominant mangrove species given to ruminants include *Rhizophora recemosa, Avicennia africana, Avicennia marina, Zanthoxyllum* zanthoxyloides, *Blutaparon vermiculare* and *Paspalum vaginatum* (Kusmana and Sukardjo, 2016; Ahouangan *et al*., 2022). The species *Rhizophora recemosa, Avicennia africana*, and *Avicennia marina* are widely preferred by small ruminants (goats and sheep) (Ahouangan *et al*., 2022; Zuhri *et al*., 2022; Akram *et al*., 2023). The mangrove biomass used by small ruminants based on research by Ahouangan *et al*. (2022) is mangrove leaves (55.55% for *Rhizophora recemosa* and 27.77% for *Avicennia africana*), bark (35.55% for *Rhizophora recemosa* and 16.66% for *Avicennia africana*) and other parts such as flowers and young stems (Ahouangan *et al*., 2022). Mangrove leaves are considered very good as a food source because they have good palatability and are supported by the habit of ruminants which are generally known to eat leaves (Kusmana and Sukristijiono, 2016). Farmers use *Zanthoxyllum zanthoxyloides* leaves as an alternative medicine to treat diarrhea and skin diseases that attack their livestock (Ahouangan *et al*., 2022). *Rhizophora racemosa* bark is used by breeders in sheep reproduction management. Feeding sheep with *Rhizophora recemosa* produces more male offspring than female offspring. Increasing the number of male offspring provides great benefits for breeders engaged in fattening (Ahouangan *et al*., 2022).

The mangrove species *Avicennia* sp has quite high crude protein, i.e., 13% based on dry matter and the leaves contain fiber (8.7%), carbohydrates (13%), vitamin B (2.64 mg/100 g), vitamin C (15.32 mg/100 g) (Ahouangan *et al*., 2022; Zuhri *et al*., 2022; Akram *et al*., 2023) and has good palatability when consumed (Ahouangan *et al*., 2022; Akram *et al*., 2023) and mangrove leaves can be an important food source for domesticated livestock in dry areas (Hoppe-Speer and Adams, 2015). Mangrove leaf-based feeding has been applied by breeders in the Cimanuk Delta residence on the North coast of West Java (Kusmana and Sukardjo, 2016). The introduction of ruminants into mangrove forests was also carried out on the North and South Coasts of Central Java. The South Coast of Central Java has an area that is often flooded during the rainy season or what is known as bonorowo.

Table 4: Productivity of mangrove species in belawan sicanang sub-district, medan belawan regency

Mangrove species	Density (Ind/ha)	Productivity (ha/year)		Capacity (AU/ha/year)
		Fresh weight (Ton)	Dry weight	
Avicennia marina	580	3.71	0.96	0.42
Bruguiera gymnorrhiza	80	0.51	0.13	0.05
Bruguiera sexangula	80	0.51	0.13	0.05
Nypa fruticans	140	0.89	0.23	0.10
Rhizophora apiculata	200	1.28	0.33	0.14
Sonneratia alba	160	1.02	0.26	0.11
Thespesia populnea	40	0.25	0.06	0.02

Source: Zuhri *et al*. (2022)

This area is often used by livestock breeders as a grazing location for ruminants, especially cows and buffalo. The *Bogowonto* area and its surroundings have *bonorowo* which is quite extensive and often flooded so this condition is used by the community to raise buffalo commodities, with the assumption that buffalo are relatively resistant to wet grass (as their main food) in grazing areas, whereas in Lukulo the *bonorowo* is narrower and tends to dry out. So the ruminant commodity chosen to be developed is beef cattle (Setyawan and Winarno, 2006). The productivity of mangroves as ruminant feed is based on research results from Zuhri *et al.* (2022), each species has different productivity (Table 4) and in Belawan sicanang sub-district, medan belawan regency the productivity reaches 8.19 tons/ha/year or equal to 2.12 tons/ha/year based on dry matter, with average utilization of 0.15 tons/ha/year and a capacity of 0.93 AU/ha/year (Zuhri *et al*., 2022).

The recommended rearing pattern for ruminants in mangrove forest areas is an intensive system and the feed is supplied using cut and carry technique. This is a solution for utilizing mangroves as an alternative food source for ruminant development. The cut and carry technique combined with feed processing techniques such as drying and preserving is a strategy for breeders to use mangroves as ruminant feed ingredients, especially when the dry season arrives (Ahouangan *et al*., 2022). The cut and carry technique in harvesting mangrove leaves is intended to allow mangroves to grow again, because with this system ruminants are not released directly (grazed) in mangrove production forest areas. Livestock grazing in mangrove forest areas has the potential to disrupt the normal function of the mangrove ecosystem and cause major damage because uncontrolled livestock movement can kill young seedlings and inhibit growth as well as damage the root system or *pneumatophores* due to step pressure by livestock (Ahouangan *et al*., 2022). The choice of intensive ruminant rearing techniques (in cages) and mangrove harvesting (cut and carry) is intended to ensure that biomass is utilized optimally, optimal ruminant productivity is achieved, minimizes the occurrence of conflicts between farmers and breeders and the mangrove ecosystem remains well maintained. In addition to considering the beneficial value of mangroves as ruminant feed, it is still necessary to pay attention to conservation aspects. It is expected that the development of ruminants in mangrove forest areas can be realized supported by the industrialization of mangrove leaf-based animal feed.

Policy on the Ruminant Development Based on Mangrove Forest

In terms of potency, East Kalimantan province has the opportunity to develop ruminants to meet food needs from livestock, especially meat. This is possible because it is supported by the availability of livestock resources, breeders, and land with various types of feed plants including mangroves which have the potential to become a feed source as well as support for technological innovation through the industrialization of mangrove leaf-based animal feed. The development of mangrove forest-based ruminants has very good prospects by utilizing available biomass, so a development model approach is needed that involves coastal communities and is economically profitable so that the welfare of coastal communities can be realized. The development of mangrove forest-based ruminants is carried out by the community (breeders) together with the government, educational institutions (universities), research institutions, and the private sector in a collaborative manner.

The government sets regulations (policies) and facilitates and monitors the flow and availability of products, including standardizing the quality of the products produced (Mayulu *et al*., 2010). The private sector and the community play a role in realizing sufficient livestock products through production activities, product processing, marketing, and product distribution (Mayulu *et al*., 2010), while academic institutions (universities) and research institutions carry out research and downstream research results related to livestock, feed (nutritional adequacy) and feed processing technology as well as disseminating information that is useful for livestock development. Government policy in livestock development tends to be top-down, which often makes things difficult for various parties, especially stakeholders, so bottom-up policies based on research results are needed. Bottom-up policies allow stakeholders and policymakers to be involved in dialogue forums where the results of discussions can be used in formulating policies and socializing them to stakeholders so that the

development of mangrove forest-based ruminants can be realized. The following are steps to formulate a mangrove forest-based ruminant development policy.

The formulation of policies related to the development of the development of mangrove forest-based ruminant needs to be supported by theories and facts/data, human resources and accurate information. The following are the steps to formulate policies for development of the development of mangrove forest-based ruminant (Fig. 3). The main steps that must be taken to produce reliable fisheries are:

1. Conduct empirical research related to the conceptual framework that will be proposed as a policy. The research is focused on: mangrove conservation, ruminant genetic excellence, mangrove species for feedstuffs, feeding techniques, and mangrove forest support capacity
2. Conduct innovation and application case studies related to mangrove leaf-based ruminant feed processing technology, and ruminant rearing techniques
3. Conduct interactive learning, training and policy support. Interactive learning and training can involve universities and research institutions, by disseminating information on research results that are useful for the development of farms and the sustainability of mangrove forest ecosystems. Interactive learning is optimized by training as a form of implementation of knowledge gained based on research results. The training conducted is related to appropriate technology for precessing feedstuffs and livestock development area demonstration plot

Policy support on a regional and national scale is needed in realizing the development of the development of mangrove forest-based ruminant even though technically various efforts to the development of the development have been carried out. The development of the development of mangrove forest-based ruminant policies need to be socialized so that they can support efforts to use mangrove biomass as ruminant feed.

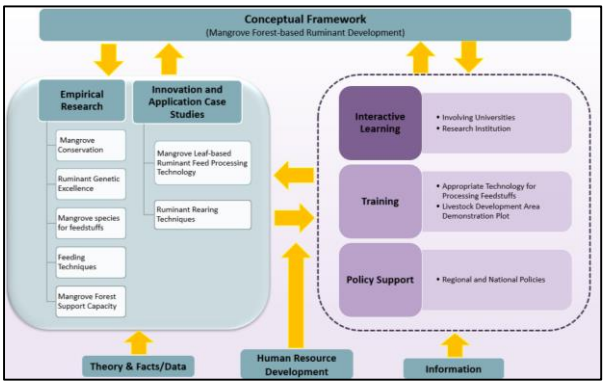

Fig. 3: Conceptual framework on the development of mangrove forest-based ruminant

Challenges and Threats in the Production of Ruminants in Mangrove Forests Area

Mangrove forests have potential as grazing land for ruminants, but breeders still have to be aware of threats that can occur, including the degradation of mangrove forests due to excessive exploitation such as uncontrolled exploitation, production of firewood and salt, and human settlements. Excessive exploitation hurts reducing land productivity, loss of flora and fauna habitat, and depletion of natural resources of mangrove forests. This condition is getting worse due to the lack of public awareness and knowledge of the function and conservation of mangrove forests so cross-sectoral, environmentally based mangrove forest management is needed sustainably (Abdunnur, 2020). Strategic efforts in sustainable mangrove forest management require the support of various parties as a collective effort including coastal communities, government, international institutions, regional institutions, national and international NGOs, the private sector, and academics (universities).

Sustainable mangrove forest management and forest protection efforts have basic principles, including (1) State responsibility; (2) Conservation and sustainability; (3) Harmony and balance; (4) Integrated; (5) Profit; (6) Circumspection; (7) Justice; (8) Ecoregion; (9) Biodiversity; (10) Participatory; (11) Local wisdom; (12) Good governance; and (13) Regional autonomy (Abdunnur, 2020). These principles are the basis for the management and protection of mangrove forests in Indonesia in general and specifically related to the use of mangrove forest areas in ruminant development. The recommended strategies based on research by Ahouangan *et al*. (2022) include (1) Reforestation of mangrove trees; (2) Logging control; (3) Management of conflicts between farmers and livestock breeders; (4) Regulate livestock access to mangrove forests; and (5) Participatory resource management (Ahouangan *et al*., 2022).

Several challenges faced in utilizing mangrove forest areas for ruminant development are limited information regarding the potential of mangrove forests for the livestock sector, lack of research related to the exploration of mangrove biomass nutrition as feedstock, no policies, regulations, and concepts for livestock development, especially ruminants in mangrove forest areas.

Conclusion

East Kalimantan province has mangrove forests that can be optimally utilized and explored as a source of local feed by livestock breeders in coastal areas, considering the important role of feed in the development of livestock commodities in a region. Mangrove species that can be given to ruminants include *Rhizophora recemosa*, *Avicennia africana*, *Avicennia marina*, *Zanthoxyllum zanthoxyloides*, *Blutaparon vermiculare* and *Paspalum*

vaginatum. The species *Rhizophora recemosa, Avicennia africana,* and *Avicennia marina* are popular with small ruminants (goats and sheep). Optimizing feed resources can be a strategy for realizing sustainability, feasibility, and production efficiency so that the use of local feedstock is expected to reduce feed costs and increase production efficiency which will provide high profits for farmers. The ruminant rearing pattern using an intensive system and providing feed using the cut and carry technique can be a solution for utilizing mangrove biomass as an alternative feed resource. It is expected that the development of ruminants in mangrove forest areas can be realized supported by the industrialization of mangrove leaf-based animal feed.

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Author's Contributions

Hamdi Mayulu: Created the idea, written, conceptualization, methodology, and funding.

Fandini Meilia Anjani: Data analysis and review. **Khoiru Indana:** Data analysis and review and editing. **Abdunnur:** Created the idea and conceptualization.

Juniza Firdha Supaningtyas and Fajar Prasetya: Review.

Declaration of Competing Interest

The authors declare no competition on financial interests or personal relationships could affect the work reported in this manuscript.

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