Conceptual Framework for Assessing Sustainability of Swamp Buffalo Production Systems

Bayu Andri Atmoko[1,2], Bryan Wisnu Prabowo[2], Ika Sumantri[3], Sigit Prastowo[4], Nuzul Widyas[4] and Tri Satya Mastuti Widi[2,*]

[1]*Research Center for Animal Husbandry, National Research and Innovation Agency, Cibinong Science Center, Jalan Raya Jakarta-Bogor, Bogor, 16915, Indonesia*

[2]*Department of Animal Production, Faculty of Animal Science, Universitas Gadjah Mada, Jl. Fauna No 3, Kampus UGM, Bulaksumur, Yogyakarta, 55281, Indonesia*

[3]*Faculty of Agriculture, Universitas Lambung Mangkurat, Jl. A. Yani Km 35.5 Banjarbaru, South Kalimantan, 70714, Indonesia*

[4]*Department of Animal Science, Faculty of Agriculture, Universitas Sebelas Maret, Jl. Ir. Sutami No.36, Surakarta, Central Java, 57126, Indonesia*

Abstract: Swamp Buffalo farming plays an important role in farmers' livelihood and in satisfying red meat demand in South Kalimantan, Indonesia. The extensive (wetland) swamp buffalo production system (SPS) and the extensive and semi-intensive dryland system (DPS) are two production systems. The production systems have high complexity and require the integrated sustainability assessment approach to measure the contribution level of sustainability indicators. This study aimed to demonstrate the conceptual framework for analyzing the sustainability of buffalo production systems in South Kalimantan. The buffalo production systems in South Kalimantan were analyzed using the comprehensive assessment framework from September-December 2021. A literature review and discussion with experts, followed by a focus group discussion to perform a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was conducted. The complex problem identifies and defines the relevant Economic, Ecological, and Societal (EES) issues, and inclusive identification and analysis of relevant stakeholders were described. Issues identified during the process were translated into relevant indicators in the EES sustainability dimensions then indicators possible for EES issues were proposed. Situation analysis in this study described and identified swamp buffalo in South Kalimantan, which is currently experiencing a population decline. The gross margin and growth and reproduction performances of the buffaloes were selected for economic benefit in both systems. Total land use and soil fertility were the possible indicators in the dimension of environment relevant for DPS, while swamp sedimentation and water pollution were considered important environmental indicators in SPS. Feed availability was measured in both systems. Social dimension indicators in both systems were focused on keeping management, the function of buffalo for livelihood, time allocation to keep buffalo, characteristics of livelihood, and possible land use conflicts.

Keywords: Economic, ecological, and societal (EES), Sustainability analysis, Sustainability indicator, SWOT analysis.

INTRODUCTION

Riverine and swamp are two species of buffaloes (*Bubalus bubalis).* The river buffalo represents approximately 75% of the total buffalo population (South and West Asia), with the remaining 25% represented by the swamp type commonly found in South East Asia and South China [1], including Indonesia, where 90% of the buffalo population is of the swamp type. In Indonesia, swamp buffalo production has been supporting the fulfillment of red meat demand, particularly in the areas where buffalo meat is more favored than beef and is used extensively in their local cuisines, such as West Sumatera, Central Java, and South Kalimantan Provinces [2,3].

Swamp buffalo (Kalimantan) in South, East, and Central Kalimantan has been existing in harmony with the human population for hundreds of years, both in social and cultural aspects. Kalimantan buffalo in South Kalimantan is divided into two production systems: extensive swamp (wetland), which represented 64% of the population; whilst the rest are both extensive and semi-intensive dryland systems. The system in swamp areas is characterized by 2-5 farmers rearing herds semi-intensively in one shared *Kalang*, a traditional wooden shelter on the swamp itself [3,4].

Nowadays, swamp buffalo has been challenged by low productive performances and a decline in the population [3], followed by consumers' preference towards Indian Buffalo Meat (IBM), imported from India since 2016. The IBM is expected to shift the role of local swamp buffalo and decrease the price of live buffalo, which will end up in lower farmers' income and motivation [2]. On the other sites, the decrease in

*Address correspondence to this author at the Department of Animal Production, Faculty of Animal Science, Universitas Gadjah Mada, Jl. Fauna No 3, Kampus UGM, Bulaksumur, Yogyakarta, 55281, Indonesia; Tel: +62274 513363; Fax: +62274 521578; E-mal: widi.tsm@ugm.ac.id

ISSN: 1927-5196 / E-ISSN: 1927-520X/23

swamp buffalo habitat is caused by the swamp's sedimentation and shifting land use. The absence of swamp buffalo in swamp areas prevised changes in the swamp ecosystem, where the vegetation became denser, leading to slower downstream and sedimentation [5].

The complexity of the buffalo production systems problem in South Kalimantan requires the integrated sustainability assessment approach which focuses on the level of sustainability indicators [6]. System theory provides concepts and tools to better understand complex developments in agriculture and society because farming systems are just one type of system in general [7]. An animal production system is considered sustainable when it can reproduce itself for a reasonable length of time and change in a timely manner when required by some conditions to continue functioning in the long term [8,9]. Sustainability assessment is a key step in supporting the development of sustainable farming systems [8]. The complexity of the buffalo production systems problem in South Kalimantan requires an integrated sustainability assessment approach that focuses on the level of sustainability indicators [6]. Indicator-based monitoring tools are frequently applied for sustainability assessments [10]. Furthermore, Meul *et al*. [10] explained that sustainable development processes should be based on integrating three pillars ecological, economic, and social (EES). The ecological condition, economic and social roles, as well as the transition to sustainable development.

Despite the critical roles buffalo production plays in providing meat, giving economic benefits and social and cultural status to farmers in South Kalimantan, the sector has not received policy-level priority. This is explained to some extent by a lack of in-depth analytical research and policy tools for this issue that will assist decision-making and priority setting. This paper is aimed to demonstrate the conceptual framework for analyzing the sustainability of buffalo production systems in South Kalimantan. The results of this study will be used as a recommendation for the sustainability indicators to be selected in measuring the overall contribution to the sustainable development of swamp buffalo production systems in South Kalimantan.

MATERIALS AND METHODS

The Conceptual Framework for Sustainability Analysis

The sustainability of buffalo production systems in South Kalimantan, Indonesia, was analyzed using the comprehensive assessment framework. It is inspired by the approaches for sustainability analysis, sustainable livelihoods, and life cycle assessment (LCA) methods. These methods were used for conducting comprehensive assessments of agricultural system innovations, including the agroecological impact at the regional level and the socio-economic impact at the household level [11-13]. According to the referred studies, there are four phases to be taken: 1). Situation (problem) description, 2). Identification and definition of relevant Economic, Ecological, and Societal (EES) issues, including relevant stakeholders. 3). Selection and quantification of suitable sustainability indicators, and 4). Aggregation of indicators information into an overall contribution to sustainable development. This study, however, underwent only phases 1 and 2 during September-December 2021 in South Kalimantan, Indonesia, by carrying out direct observation; literature study and reviews; discussion with experts and key persons, and focus group discussion.

Description of (Problem) Situation

Describing the problem of buffalo production systems was inclusive of activities of literature reviews and discussion with experts. We included all aspects/issues that are relevant with respect to sustainability. We performed a SWOT analysis to gain insight into (un)sustainable aspects of the problem. We defined buffalo production systems in South Kalimantan.

Identification and Definition of Relevant EES Issues

Relevant issues were identified based on the literature reviews and discussions with experts. The issue was developed as an indicator that shall meet the criteria of sustainability indicators. Some criteria for selecting sustainability indicators are relevance, simplicity, sensitivity, validity, target value, and accessibility data. In this paper, qualitative and/or quantitative indicators were selected. For each selected issue, indicators have to be defined and assessed. The issues and indicators are placed in the different aggregation levels with which they are associated [11,13]. Once the stakeholders, issues, and indicators have been identified and selected, the indicator scores need to be assessed.

Identification and Analysis of Relevant Stakeholders

Stakeholders' identification was conducted through a literature review and discussion with key informants.

The selected key informants consisted of farmers and local government. A literature review was carried out by reviewing relevant research publications concerning buffalo production systems in Indonesia and worldwide. A focused group discussion (FGD) was conducted in South Kalimantan by inviting buffalo farmers from both wetland/swamp (three participants) and dryland (five participants) areas; six local governments on the areas of livestock development and landscape spatial planning; and two scientists. In total, 16 participants were facilitated by researchers during FGD. A SWOT analysis was done during FGD. Issues were selected based on the frequencies raised in the SWOT analysis. The criteria to select sustainability indicators were simplicity (in which the information should be presented easily and understandable); sensitivity, which relates to the ability of an indicator to measure (sense) actual changes of the issue in the system; validity, in which a measurement is valid if it is both accurate and precise; the trend of target value; and accessible data, meaning that indicators are based on accessible data and the information is available or can be gathered while there is still time to act [14]. For each selected issue, we defined potential indicators that met the abovementioned criteria. Both qualitative and quantitative indicators were documented.

RESULTS AND DISCUSSION

Situation (Problem) Description

South Kalimantan Province consists of two geographical conditions, wetlands (lowland areas) and highlands (mountain areas). The Banjar community is made up of indigenous peoples inhabiting the South Kalimantan. Swamp buffalo in South Kalimantan, especially in wetland (swamp) areas, have been in harmony with the community's social culture for hundreds of years. The two production systems, the swamp production system (SPS) and the dryland production system (DPS), have different characteristics. As much as 64% of the buffalo population in South Kalimantan are semi-intensively kept in swamp areas, and the rest of the population is extensively kept in dryland, locally named *kerbau Gunung* or hilly buffalo [15]. Both SPS and DPS are facing similar problems of a decrease in population. The swamp buffalo population in South Kalimantan has decreased by 25.99% or 6,908 heads from 2015 (26,582 heads) to 2020 (19,674 heads). The biggest decline occurred from 2017 to 2018, which reached 30.4% [16]; yet, the problems originated from different roots. The important issue that occurred in SPS is that buffalo productivity decreased due to the decline in the carrying capacity of the swamp areas, whereas in DPS, the problem occurs due to a conflict of interest between farmers, plantation owners, and local government regarding the grazing areas.

Swamp buffaloes in South Kalimantan are mostly populated in the Hulu Sungai Utara (HSU) District, which, based on *a location quotient* value of 9.46, indicates buffalo are prominent livestock in this area [16]. The swamp ecosystem is characterized by the existence of water vegetations such as water hyacinth and *Oryza sativa forma spontanea L* (locally named *Padihiang*), *Paspalum sp* (locally named *Kumpai Batu*), and *Hymenachne amplexicaulis haes* (*Kumpai Minyak*) which serve as main feeds for swamp buffalo [17]. In those areas, *kalangs* are built above the river water; made from wooden logs using Ironwood (*Eusideroxylon zwageri T. et. B.),* which are assembled as a huge raft and fenced [18]. Swamp buffaloes wallow in the deep swamp and swims around to graze; Yusnizar *et al*. [19] reported that the swimming distance of swamp buffalo could reach 75 km^2.

The population of swamp buffalo in SPS has been decreasing in recent years due to low productivity and reproductive performance. With this notice, the healthcare program could not be applied efficiently due to the nature of the extensive *Kalang* production system; hence, the mortality rate, especially in the calf, is extraordinarily high. Further, swamp areas are threatened by sedimentation and shifting of land use, leading to decreased forage availability. Farmers in SPS keep their buffalo under traditional practices, which rely merely on swamp local resources.

The Dryland swamp buffalo production system is characterized by extensive systems in natural pasture lands or forests and semi-intensively integrated with plantations, especially rubber and oil palm. The horizontal conflict currently occurs between farmers and the local government, who issued regulation of the Local Regulation Decree of Tanah Bumbu District Number 9, the Year 2018, regarding the general discipline and public serenity mentioned in Chapter 10 and Paragraph 1: “Every individual or entity that own animals are obliged to keep them in the barns/housing and not to let the animals grazing in public or protected areas which potentially disturb the public activities and imperil the public traffic and harmful for the environment”. This regulation specifically restricts buffalo farming in DPS.

Aside from the mentioned regulation, there is also a conflict between farmers and plantation management, where the buffaloes are grazing illegally in the plantation areas. The plantation owners demand that the farmers house their buffaloes. Farmers ought to invest in housing and fencing to keep their animals, which is costly. On the other hand, by housing the animals, they also have to spend resources on providing feeds for their animals. As a result of these conflicts, farmers decided to sell their buffaloes and shift their activities to other sectors.

The main problem common in both buffalo farming systems is shifting land use, leading to conflicts among farmers, the community, and the government. Local government does not consider the livestock sector as a significant contribution to the regional income; they only focus on using the land for plantation. Farmers have felt less secure for the last couple of decades with regard to the ownership of the land for buffalo production. This situation also resulted in a decrease in the buffalo population. The decrease in buffalo population in South Kalimantan is predicted to bring multiplier effects to the farmer's welfare (economic dimension), further sedimentation on the swamp ecosystem (environment dimension), and changes in the local wisdom of the local community (social dimension).

Identification and Analysis of Stakeholders

Stakeholders were determined based on their relevance to the problem contexts. We identified primary and secondary stakeholders through literature reviews and FGD. No specific differences between stakeholders in both systems, as they have similar importance to the systems and interests. Table **1** presents the identification and analysis of buffalo production stakeholders.

Based on Table **1**, the Livestock Service Bureau is the representative of local government concerns on increasing buffalo population by intensively assisting the management practices. However, the policy of land use and spatial planning seems to be working against the Livestock Service Bureau, as they only focus the

Table 1: Identification and Analysis of Buffalo Production Stakeholders in South Kalimantan

Stakeholders	Importance to system	Interest
Primary		
Farmers	Play the main role	Income, savings, and social status
Central Government	Policymakers at national level in terms of: Livestock slaughtering Import of Indian Buffalo Meat (IBM) Supply and demand of meat	National agenda to meet the demand for red meat
Local Government	Policymakers at regional level in terms of: Development of swamp buffalo Spatial planning and Land use Conservation of swamp ecosystem Permission of land use and ownership	Increase in buffalo population Synchronization of the livestock sector and other sectors such as plantation, fisheries, and mining Swamp ecosystem conservation
Secondary		
Scientist/academicians	Conducting studies on buffalo production as baseline considerations for policymakers	Publication and policy papers
Traders/		
Butcher/	Slaughtering	Profit
Meat sellers	Influence the supply and prices of meat and consumer preferences	Profit
Oil palm plantation (OPP) Company	Provide undergrowth in oil palm plantation land for buffalo grazing* Expanding their plantation on swamp areas**	Profit
Mining company	Provide post-mining land for buffalo production*	Profit
Consumers	Influence the supply and demand	Preference towards buffalo meat

*Specific on dry production (DPS) system of buffalo in South Kalimantan.
**Specific on a swamp production system (SPS) of buffalo in South Kalimantan.

land use for plantation. The different concerns and roles implied contradictive actions. Land use regulation has an impact on decreasing the buffalo population since the development plan is prioritized for the extraction sector and oil palm plantation when in contrast, the livestock sector will be limited and suppressed. The livestock sector is assumed to give a less significant contribution to regional development due to smallholding ownership. Shall it continuously occur, the decline in the livestock sector as a protein source producer in those areas is unavoidable; as stated by Nziguheba *et al*. [20] that land degradation threatens food production, particularly in smallholder farming systems.

We discovered butchers, traders, scientists, and OPP (or mining companies) as secondary stakeholders. Their roles were either as a support or an obstacle to buffalo farming development. Butchers and traders can support buffalo development in determining the supply of buffalo meat. Sumantri and Chang [2] reported that buffalo meat consumption in South Kalimantan increased along with the increase of Indian buffalo meat (IBM) importation, which was from 38 tons in 2017 to 675 tons in 2019, which mainly utilized for producing meatballs, catering, and restaurant needs. Buffalo meat production in South Kalimantan will contribute 10.21% of meat production in 2021. This showed big market potential for buffalo meat. Buffalo meat may be considered a good option to meet the increasing demand for food for human consumption [21].

Oil palm plantations and mining are leading sectors and main income sources for the Province of South Kalimantan. Oil palm plantation covers about 427,000 Ha, while coal mining covers 566,000 Ha [22]. It is projected that both sectors will increase and place pressure on buffalo production in SSP as well as in DPS. Similarly, OPP and mining companies can either support or obstruct buffalo farming development. On the other side, however, OPP is the potential to be integrated with buffalo farming, as OPP can provide undergrowth vegetation for buffaloes, and in return, buffaloes provide animal draught power to transport palm oil fruit bunches during harvest [23]. This is in line with the potential of reclaimed post-mining lands as grazing areas for buffalo. According to Minister of Forestry regulations (yr. 2009-2014), post-mining lands have to be returned to their ecological and social functions through reclamation. Reclaimed lands can be utilized for activities of agriculture. Utilization of post-mining lands as grazing areas could increase livestock population and meat production [24].

Participatory SWOT Analysis

Participatory SWOT analysis was started with a brainstorming session among FGD's participants to list relevant aspects for the sustainable development of buffalo production systems in South Kalimantan Province. Tables **2** and **3** present the SWOT analysis results of buffalo production systems in South Kalimantan, collected from various stakeholders' participants who actively had discussions during the FGD.

Most stakeholders agreed that buffalo production benefits farmers economically, provides red meat for South Kalimantan residents, and maintains the swamp ecosystem and social and cultural tradition of the community. Buffalo has good adaptability to local conditions and is able to utilize low-quality feeds; also, they can be maintained extensively with minimum inputs. Those are considered strengths of buffalo production. At the higher (regional) level, buffalo production can be an alternative to reduce the dependency on extractive industries; later, it can be considered an opportunity. However, as in other areas in Indonesia, buffalo production in South Kalimantan depends only on local resources, without any improvement, as it is limited by distance and shrinkage of grazing lands.

Other major problems buffalo farmers face are low reproductive efficiency and prolonged inter-calving intervals [25,26]. The reproduction efficiency of buffalo is determined by 1). inherent late maturity, 2) poor estrus expression in summer, 3) distinct seasonal reproductive patterns, and 4) prolonged inter-calving intervals [27]. Furthermore, Azawi *et al*. [26] reported that 35.4% of buffalo have smaller follicles (less than 8 mm) compared to cattle. The estrus cycle of swamp buffalo is 20-22 days, with an average estrous duration is 19.9±4.4 h, and ovulation occurs 13.9 h after estrus [27]. The repeated and long reproduction cycle of buffalo can result in economic losses [28]. Widi *et al*. [3] reported the calving interval of swamp buffalo (*kalang*) is 16.5 months, and in line with swamp buffalo in East Java is 16.39 months [29]. This condition is worsened by the high mortality rate of pre-weaning calves, particularly during the rainy season in a swamp area, when the water level is high and the calves were left behind on the shelter (*kalang*) while their cows are swimming and grazing. This causes the calves to

Table 2: SWOT/SW Analysis of Buffalo Production Systems in South Kalimantan

Stakeholder	Strengths	Weaknesses
Primary stakeholders		
Farmers	Buffalo as savings Local identity Supply of red meat Easy management Good reproduction Male buffalo give more benefits Less diseases Power traction	Lack attention from the government Lack of animal health support and assistance More disease during rainy season Calves' diseases Long reproduction cycle Not popular
Regional government	Provide animal source food Income for farmers Suitable for swamp area and can swim Good grazer Easy management Good body size Good reproduction	Lack human resources Traditional practices Difficult to handle individually for health treatment Not resistant to high temperature High mortality of calves during high water level
Secondary stakeholders		
Scientist / academicians	Highly adapted to climate Good reproduction Good conversion of low-quality feeds	Extensive system
Spatial planning bureau	Improve economic benefit of the farmers	Less additional values from swamp buffalo Less popular and less attractive, compared to extractive sectors such as mining.

Table 3: SWOT/OT Analysis of Buffalo Production Systems in South Kalimantan

Stakeholder	Opportunities	Threats
Primary stakeholders		
Farmer	High demand for religious festivities High preference for their meat due to lower price compared to beef Easy to sell	Shortage of lands Competition with fisheries Conflict with the plantation sector High criminal target Feed resources become limited
Livestock Service Bureau	Synchronization of estrus to minimize silent heat Artificial insemination for semi-intensive system High demand for meat South Kalimantan is the gate to the new capital city in East Kalimantan	Water pollution Habitat for living decreases Inbreeding Slaughter of productive female
Secondary stakeholders		
Scientist/academicians	Opportunity for keeping buffalo in OPP and post-mining lands Agrotourism potential Breeding and fattening potential Post-harvest processing	Shifting land use Inbreeding Livestock thievery No legal protection for farmers Low availability of feed resources due to land use shifting and sedimentation
Spatial planning bureau	Less dependency on the mining sector South Kalimantan as a gate of the new capital city in East Kalimantan	Unsynchronized spatial policy among sectors The livestock sector is not the main priority of regional development Incompatible land allocation for the livestock sector

Table 4: Identification of Sustainability EES Indicators of Buffalo Production Systems in South Kalimantan

EES issues	Issues	Sustainability Indicators	Level/hierarchy
Economic	Economically benefit	Farmer's income; Gross margin (GM)	Farm, regional
		Buffalo performances (growth and reproduction rate)	Farm
Environmental	Land use and quality	Total land use	Regional, Global
		Soil fertility	Regional, Global
		Feed availability (carrying capacity; botanical composition)	Farm, regional
		Swamp sedimentation	Farm
	Water quality	Water pollution	Farm, regional, and global
Social	Buffalo management practices	Farm size, feeding system, mating system, housing, recording, time allocated for buffalo keeping	Farm
	Human well-being	Farmer educational level	Farm
	Additional functions of buffalo	Social status, saving, insurance, manure, draught power, culture, religious festivity, meat production (alternative to beef)	Farm, regional
	Health and diseases	Buffalo diseases or health problems	Farm
	Social conflict	Local regulations, land use conflicts	Regional

receive insufficient feed and hence, nutrients. The mortality rate of swamp buffalo calves in *kalang* system was about 20 – 40% per year [3], with various causes such as malnutrition, diseases, and accident (falling down and being trapped) in the *kalang* basement.

The livestock sector has not been prioritized in the spatial management policy because of its lower popularity compared to the other sector(s), such as mining and oil palm plantation, which significantly contribute the regional income. During FGD, both SPS and DPS farmers, as well as local government officers (Table **2**), mentioned that the reproduction traits of swamp buffalo are good, which can be interpreted that the keeping management of buffalo is effortless; as the buffaloes get mated and bred naturally during grazing or when in the *kalang*. It is discovered that buffaloes in these systems are difficult to handle individually, resulting the difficulty in health treatment. Fasciolosis disease, caused by infection of *Fasciola hepatica*, was found mainly on swamp buffaloes and had been causing deaths, particularly in *kalang* system.

Table **3** presents the opportunities and threats analysis. The high preference of people in South Kalimantan is considered an opportunity for the buffalo sector. Buffalo is preferable for religious festivities, which suits the strong religious tradition in South Kalimantan. Another opportunity revealed by stakeholders during FGD was the plan for the capital city relocation to East Kalimantan, which shares its border with South Kalimantan. The demand for red meat is expected to increase in the future due to the relocation.

Identification of EES Sustainability Issues

Table **4** provides selected sustainability indicators for buffalo production systems in South Kalimantan, while Table **5**. defines the selected indicators possible for EES issues. Relevant potential indicators (as shown in Table **4**) were selected based on the process results of the subsequent literature study and expert consultations and confirmed by participatory SWOT analysis. For each selected issue, we determined possible indicators (Table **5**) as they fulfill the required criteria, such as relevant, realistic, and end-user value.

The selected indicator for economic benefit was represented by gross margin rather than farmer's income, which is based on financial revenues minus variable cost. This indicator has an impact on the farm level. Performances of the animals are also an important indicator for economic issues, represented by growth and reproduction rates and meat production, which can be measured at the farm level.

A conceptual framework for EES indicators of buffalo production systems in South Kalimantan is presented in Figure **1**. The conceptual framework can be transformed in the context of buffalo production

Table 5: Selected Indicators Possible for EES Issues and their Definitions

Possible indicator	Definition
Economic	
Gross margin (GM) (IDR / hour)	GM (financial revenues reduced by variable costs) per hour per day
Buffalo performances	
Genetics	The genetic parameters are the building blocks that determine an individual's potential.
Growth	
Live/body weight (Kg)	Live-weight female buffalo aged more than 2 years
Weaning weight (Kg)	Live weight at weaning
Yearling weight (Kg)	Live weight at yearling (± 11 months)
Reproduction (calf crop (%))	Survived weaned calves in a year in the percentage of the total female buffalo population
Meat production (kg)	Amount of meat produced by an adult buffalo
Environmental	
Total land use (m^2 per kg BW)	Space of land required to produce one unit product of buffalo
Soil fertility (macro and microelements)	Amount of macro and micro elements of soil where the buffaloes are kept
Feed availability	
Consumption of dry matter (DM) (DM, g $BW^{-0.75}$/day)	Amount of feed in DM consumed by an animal per kg metabolite BW in a day
Consumption of crude protein (CP) (CP, g $BW^{-0.75}$/ day)	Amount of feed protein consumed by an animal per kg metabolite BW in a day
Swamp sedimentation rate (mg/dt/m^2)	The average amount of sediment contained in the swamp area where the buffaloes are kept.
Water pollution	
Total Coliform (MPN/100ml)	Amount of coliform in 100 ml of water
Level of E. Coli (MPN/100ml)	Amount of E. coli in 100 ml of water
Water pH	Acidity level of water in buffalo areas
Social	
Farm size (head)	Number of buffalo kept by farmers
Feeding system Mating system Housing Recording Time allocated for buffalo keeping	Feeds gathering and offering methods Mating methods (artificial insemination or natural) Structure and construction of the house where buffaloes are maintained (permanent or semi-permanent) Availability of recording system Amount of time in a day used by farmers to maintain the buffaloes
Farmer's educational level	Education of the farmers
Social status Manure (kg/day) Culture (head/ event) Religious festivity	Number of buffaloes owned by the farmers Amount of feces produced by a buffalo per day Number of buffaloes slaughtered in a cultural event Number of buffaloes slaughtered in a religious festivity
Buffalo health problems (%)	Percentage of sick buffaloes in a herd
Conflict on land use (number of conflict evidence in a year)	The number of conflicts on land use between buffalo keeping and other activities such as plantation, mining, and fishery.

systems sustainability as a tool for describing the complex situation in the two buffalo production systems in South Kalimantan. Important components to monitor sustainability are thus: 1) participatory approach to identify and select sustainability issues and indicators; 2) Data availability to assess and evaluate the sustainability indicators of animal production systems empirically [12]. This study aimed to focus on the first

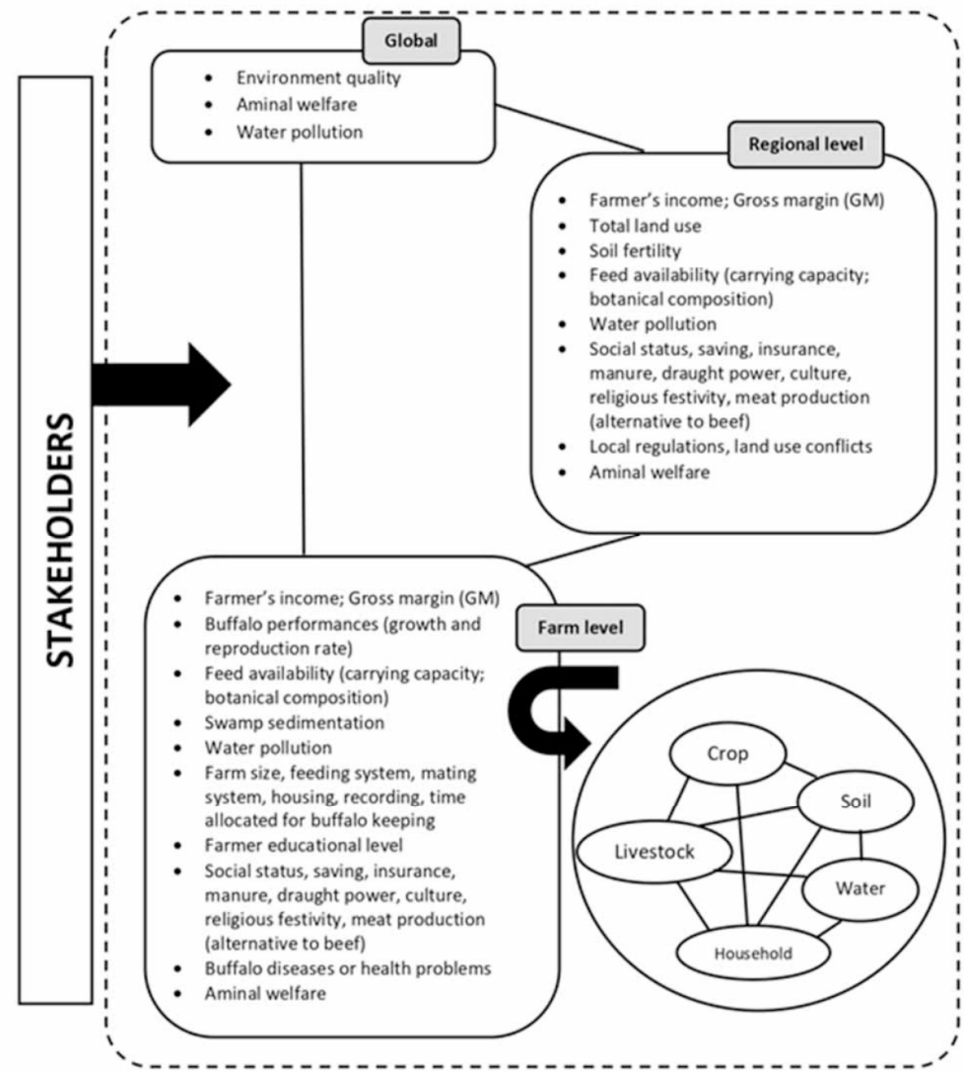

Figure 1: A conceptual framework for EES indicators of buffalo production systems in South Kalimantan.

component and carried out carefully to prepare the second one, which will assess and evaluate the contribution of each sustainability indicator to overall sustainable development). The challenge to designing the swamp buffalo production systems, hence, is to select a set of indicators that can comprehensively and reliably represent the complexity of the current production systems, ecological conditions, economic and social roles, and the transition to sustainable development. We define this figure to the other because these are the study's main results.

CONCLUSION

Situation analysis in this study was able to describe and identify the complexity of the problems, both actual and potential, in the development of swamp buffalo in South Kalimantan, which is currently experiencing population decline. Farmers and central and local governments were identified as primary stakeholders, whereas the secondary stakeholders were scientists/academicians, traders, butchers, meat sellers, Oil Palm Plantation companies, mining companies, and consumers.

Issues identified during that process are translated into relevant indicators in the EES sustainability dimensions, and some indicators possible for EES issues were proposed. The gross margin and growth and reproduction performances of the buffaloes were selected to indicate economic benefit in both systems. Total land use and soil fertility were possible indicators in the dimension of environment relevant for DPS, while swamp sedimentation and water pollution were considered important environmental indicators in SPS. The feed availability issue was relevant in both systems. Keeping management, the function of buffalo for livelihood, time allocation to keep buffalo,

characteristics of livelihood, and possible land use conflicts were considered to be relevant for the social dimension in both systems.

ACKNOWLEDGEMENT

The authors would like to thank the Directorate of Research, Reputation Improvement Team Towards World Class University, and Quality Assurances Office of Universitas Gadjah Mada, who have founded this research with Letter of Assignment no: 6144/UN1.P.III/DIT-LIT/PT/2021.

DECLARATION OF CONFLICTING INTERESTS

We confirm that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

REFERENCES

[1] Deb GK, Nahar TN, Duran PG, Presicce GA. Safe and sustainable traditional production: the water buffalo in Asia. Frontiers in Environmental Science 2016; 4(38): 1-7. https://10.3389/fenvs.2016.00038

[2] Sumantri I, Chang HS. Impact of imported Indian buffalo meat on red meat supply and demand in South Kalimantan, Indonesia. IOP Conf Series: Earth and Environmental Science 2021; 902: 012033. https://doi.org/10.1088/1755-1315/902/1/012033

[3] Widi TSM, Prastowo S, Sulaiman A, Hulfa R, Sumantri I. Reproductive characteristics of female swamp buffalo reared under kalang production system in South Kalimantan. IOP Conf Series: Earth and Environmental Science 2021; 902: 012041. https://doi.org/10.1088/1755-1315/902/1/012041

[4] Rochgiyanti, Susanto H. Transformation of wetland local wisdom values on activities of swamp buffalo breeding in social science learning practice. Advances in Social Science, Education, and Humanities Research 2017; 147: 272-276. https://doi.org/10.2991/icsse-17.2018.62

[5] Sulaiman A, Rusmayadi G, Septiana M, Riyadi M. Kajian daya dukung wilayah terhadap produksi ternak kerbau rawa di Kecamatan Daha Barat, Hulu Sungai Selatan. In Prosiding Pengelolaan Sumberdaya Lahan Sub Optimal untuk Produksi Biomassa Berkelanjutan. Report, Fakultas Pertanian, Universitas Lambung Mangkurat 2013.

[6] Ten Napel J, van der Veen AA, Oosting SJ, Koerkamp PWGG. A conceptual approach to design livestock production n systems for robustness to enhance sustainability. Livestock Science 2011; 139: 150-160. https://doi.org/10.1016/j.livsci.2011.03.007

[7] Schiere JB, van der Hoek R. Livestock keeping in urban areas. A review of traditional technologies based on literature and field experience. FAO animal production and health 2014; paper No. 151.

[8] Labecg T, Baret PV, Stilmant D. Sustainability indicator for livestock farming. A review. Agronomy for Sustainable Development 2013; 33: 311-327. https://doi.org/10.1007/s13593-012-0121-x

[9] Martin G, Barth K, Benoit M, Brock C, Destruel M, Dumont B, Grillot M, Hubner S, Magne M, Moerman M, Mosnier C, Persons D, Ronchi B, Schanz L, Steinmetz L, Werne S, Winckler C, Primi R. Potential of multi-species livestock farming to improve the sustainability of livestock farms: A review. Agricultural System 2020; 181: 102821. https://doi.org/10.1016/j.agsy.2020.102821

[10] Meul M, van Passel S, Nevens F, Dessein J, Rogge E, Mulier A, van Hauwermeiren A. MOTIFS: A monitoring tool for integrated farm sustainability. Agronomy for Sustainable Development 2008; 28(2): 321-332. https://doi.org/10.1051/agro:2008001

[11] Mollenhorst H. How to House a Hen. Assessing Sustainable Development of Egg Production System. Ph.D. Thesis, Wageningen University, The Netherlands, 2005; p. 136. Available at: https://library.wur.nl/WebQuery/wurpubs/fulltext/27952

[12] Widi TSM, Udo H, Oldenbroek K, Budisatria IGS, Baliarti E, van der Zijpp A. Designing genetic impact assessment for crossbreeding with the exotic beef breed in the mixed farming system. Outlook on Agriculture 2020; 50(1): 34-45. https://doi.org/10.1177/0030727020915206

[13] Mollenhorst H, de Boer HMJ. Identifying sustainability issues using participatory SWOT analysis: a case study of egg production in the Netherlands. Outlook on Agriculture 2004; 33(4): 267-276. https://doi.org/10.5367/0000000042664747

[14] Nathan HSK, Reddy BS. Criteria selection framework for sustainable development indicators. International Journal of Multicriteria Decision Making 2011; 1(3): 257-279. https://doi.org/10.1504/IJMCDM.2011.041189

[15] Sumantri I, Widi TSM, Widyas N, Habibah, Albana H. Morphometrics and carcass production of Kalimantan swamp buffalo under extensive production system (kalang). Livestock Research for Rural Development 2022; 34(3). http://www.lrrd.org/lrrd34/3/3415isuma.html.

[16] BPS-Statistics Indonesia. The Buffalo Population in Indonesia by Provinces 2010-2020. The BPS-Statistics Indonesia. Jakarta 2021. https://www.bps.go.id/indicator/24/471/2/buffalo-population-by-province.html

[17] Agusliani E, Darmadji D. Keanekaragaman hayati di rawa Danau Panggang Kabupaten Hulu Sungai Utara. Enviro Scienteae 2017; 13(3): 187-194. https://doi.org/10.20527/es.v13i3.4305

[18] Arifin YR, Itta D. The potency of ulin (Eusideroxylon zwagery T. et. B) for supporting Banjarese building construction in wetland architecture. Journal of Wetlands Environmental Management 2013; 1(1): 61-64. https://doi.org/10.20527/jwem.01.01.03

[19] Yusnizar Y, Ilham M, Rizal M, Sumantri C. Kerbau, Ternak Potensial yang Terlupakan. Bogor: Edu Pustaka 2015; pp. 19-20.

[20] Nziguheba G, Adewopo J, Masso C, Nabahungu NL, Six J, Seguya H, Taulya G, Vanlauwe B. Assessment of sustainable land use: linking land management practices to sustainable land use indicators. International Journal of Agricultural Sustainability 2022; 20(3): 265-288. https://doi.org/10.1080/14735903.2021.1926150

[21] Guerrero-Lagerta I, Napolitano F, Cruz-Monteroza R, Mota-Rojas D, Mora-Medina P, Ramirez-Bribiesca E, Bertoni A, Berdugo-Guiterrez, Braghieri A. River buffalo meat production and quality: sustainability, productivity, nutritional and sensory properties. Journal of Buffalo Science 2020; 9: 159-169. https://doi.org/10.6000/1927-520X.2020.09.17

[22] BPS Kalimantan Selatan. South Kalimantan in Figure 2022. Badan Pusar Statistik Provinsi Kalimantan Selatan. Banjarmasin 2022. https://kalsel.bps.go.id/publication/2022/02/25/2d212455a03806fc8befa9f5/provinsi-kalimantan-selatan-dalam-angka-2022.html

[23] Grinnell NA, van der Linden A, Azhar B, Nobilly F, Slingerland M. Cattle-oil palm integration – a viable strategy to increase Malaysian beef self-sufficiency and palm oil sustainability. Livestock Science 2022; 259: 104902. https://doi.org/10.1016/j.livsci.2022.104902

[24] Dee Whittier W, Gerken HJ, Zipper CE. Management of cow-calf production on reclaimed surfaced-mined land. Virginia Cooperative Extention 2010; 460-128. Available at: https://vtechworks.lib.vt.edu/bitstream/handle/10919/50731/460-128.pdf?sequence=1&isAllowed=y

[25] Abo-Farw MA, Nagy WM, Abdel-Khalek AE. Effect of post-mating treatment with controlled internal drug release (cidr) on pregnancy rate of repeat breeder Egyptian buffaloes. Journal of Animal Health and Production 2021; 9(4): 504-511. https://doi.org/10.17582/journal.jahp/2021/9.4.504.511

[26] Azawi OI, Ali AJ, Noaman UT. A study on the ovarian follicular dynamic in Iraqi Northern Buffalo. Tropical Animal Health and Production 2009; 41: 79-83. https://doi.org/10.1007/s11250-008-9156-z

[27] Singh J, Nanda AS, Adams GP. The reproductive pattern and efficiency of female buffaloes. Animal Reproduction Science 2000; 60-61: 593-604. https://doi.org/10.1007/s11250-019-01811-7

[28] Safari A, Shadparvar AA, Hossein-Zadeh NG, Abdollahi-Arphanahi R. Economic values and selection indices for production and reproduction traits of Iranian buffaloes. Tropical Animal Health and Production 2019; 51(5): 1209-1214. https://doi.org/10.1007/s11250-019-01811-7

[29] Budiarto A, Hakim L, Ciptadi G, Nasich M, Putri ARI, Karima NK, Prasetyo YDA. The productivity estimation of female swamp buffalo population with different ages group in district Lumajang, East Java. IOP Conf Series: Earth and Environmental Science 2021; 743: 012053. https://doi.org/10.1088/1755-1315/743/1/012053

Received on 16-03-2023 Accepted on 17-04-2023 Published on 28-04-2023

https://doi.org/10.6000/1927-520X.2023.12.06