Conceptual Model for Mitigating Human – Wildlife Conflict based on System Thinking

Pindi Patana¹, Herman Mawengkang², Maya Silvi Lydia³
¹Graduate School of Environment Management/Faculty of Forestry, University of Sumatera Utara, Medan, Indonesia
²Department of Mathematics, University of Sumatera Utara, Medan, Indonesia
³Faculty of Computer Science and Information Technology, University of Sumatera Utara, Medan, Indonesia
¹pindipatana@gmail.com

Abstract. In conservation process it is unavoidably that conflict incidents may occur among the people and wild-life in the surrounding of the conservation area. Mitigating conflict between wildlife and people is considered a top conservation priority, particularly in landscapes where high densities of people and wildlife co-occur. This conflict is also happened in Leuser conservation area located in the border of North Sumatra and Aceh province, Indonesia. Easing the conflict problem is very difficult. This paper proposes a conceptual model based on system thinking to explore factors that may have great influence on the conflict and to figure out mitigating the conflict. We show how this conceptual framework can be utilized to analyze the conflict occur and further how it could used to develop a multi-criteria decision model.

Keywords: Conflict, conservation, conceptual model, system thinking

1. Introduction
Whenever a conservation takes place, particularly for a forest, a conflict between human and wildlife (HWC) could happen unavoidably. Analog with the meaning of a conflict, HWC can be defined as interaction between humans and wildlife that results in negative impacts on human social, economic or cultural life, on the conservation of wildlife populations, or on the environment. This issue has negative meaning due to the fact that it could destruct the effective conservation and also to prevent economic development and resource sustainability ([1]; [2]).

A set of global trends relating to human populations, habitat evolution and animal distribution and behaviour has contributed to the escalation of human-wildlife conflict worldwide. While humans and wildlife have co-existed for millennia, the frequency of conflicts involving problem animals has grown in recent decades, mainly because of the exponential increase in human populations and consequent expansion of human activities ([3]; [1]), partition of wildlife distributions ([4]; [5]; [6]), and natural of landscape characteristics ([7]).

Responses to tackle these conflicts are varied. However, when conflicts are handled improperly, they can create continuing public frustration, further reducing the credibility of the board which administers the program and detracting from long-term objectives ([8]; [9]). Some authors are finding that conflict management approaches can be used effectively to manage the HWC ([8]; [9]; [10]).

[11] propose a decision modeling based on multicriteria analysis to resolve human-wildlife conflicts, which requires the participation of local communities and other stakeholder groups. [2] suggests that social factors should be considered in resolving effectively HWC. He points out that
direct wildlife damage is the main driver of conflict. Technical approaches which are usually used to limit the damage ([4]; [12]) cannot be expected to lessen the conflict. However, we argue for his approach could handle HWC effectively, as there are other factors beside social should be involved. HWC can be regarded as a complex system. In order to mitigate the conflict we need to include the whole elements in the system.

[13] use mental models to analyze HWC from the perspective of a social-ecological system in Namibia. They explore the process of mind mapping to get insight the understanding of HWC in a social-ecological system. They show that the model could be used to indicate significant variables in easing the conflict.

[14] also consider the HWC in terms of social dimensions. Therefore they use multi criteria decision analysis (MCDA) as a decision support tool to evaluate the management of how to reduce HWC. [7] point out that although landscape characteristics is crucial in affecting human-wildlife interactions, it is necessary to have a better insight the mechanisms that drive those interactions. As there are many factors involved, they use a conceptual model to integrate those factors in such a way to provide a decision making model at multiple objectives.

Indicators derived from social science also focus on wildlife population size as an independent variable. Metrics such as the sociological carrying capacity [15] have been used to understand the diversity of stakeholder viewpoints related to wildlife management. Regardless of metrics, ecological and social frameworks consistently describe wildlife population size as a primary driver of human-wildlife interactions leading to conflict. Fewer conceptual frameworks have integrated ecological and social factors that affect human-wildlife interactions. This paper is concerned with HWC occurred in the Leuser Landscape. We address a conceptual framework to mitigate the conflict. We use system thinking to describe inter-relationship among the component of the system human-wildlife as a whole.

2. Leuser Landscape
The Leuser Landscape is an area of forest located in the provinces of Aceh and North Sumatra on the island of Sumatra in Indonesia. Covering more than 2.6 million hectares it is one of the richest expanses of tropical rain forest in Southeast Asia and is the last place on earth where sumatra elephant, sumatran rhinoceros, sumatran tiger and sumatran orangutan are found within one area. It has one of the world's richest yet least-known forest systems, and its vegetation is an important source of Earth's oxygen.It is among the most biodiverse and ancient ecosystems ever documented by science.

The ecosystem stretches from the coast of the Indian Ocean to the Malacca Straits. It encompasses two vast mountain ranges including Mount Leuser that reaches 3455m, two major volcanoes, three lakes and more than nine major river systems. As well as providing habitats for a number of endangered wildlife species, the ecosystem acts as a life support for approximately four million people who live around it by providing a steady supply of water, soil fertility, flood control, climate regulation and pest mitigation.

The Leuser Ecosystem comprises one of the remaining examples of Indo-Malayan (Malesian) vegetation communities with an estimated 45% of the approximately 10 000 recorded plant species. In general the ecosystem can be characterised as a montane rainforest community. However, the typical vegetation type up to an altitude of 600 metres is moist tropical lowland forest characterised by multi-layered stories with emergent trees reaching between 45 and 60 metres in height and high densities of fruit tree species. The large variety of tree species found in Leuser represent virtually all life-strategies of trees, from root flowering and trunk flowering to common twig flowering types. Among the most important and impressive trees are the several species of strangling fig. The largest flower on earth; the parasitic Rafflesia is a relatively common in the ecosystem.

3. System Thinking
The approach of systems thinking is to consider of any given issue, such as HWC, as a whole, emphasizing interrelationships between components rather than the components themselves. It does not try to break systems down into parts in order to understand them; instead, it focuses attention on
how the parts act together in networks of interactions. Systems thinking is not a discipline, but rather an interdisciplinary conceptual framework used in a wide range of areas.

Despite the absence of a commonly accepted definition for systems thinking, the diverse available definitions clearly yield two main complementary meanings for systems thinking: rising above the separate components to see the whole system, and thinking about each separate component as a part of the whole system. Systems thinking is considered an effective means of facing real-world situations.

Systems thinking is not a new concept, however, it is increasingly being regarded as a new way to understand and manage complex problems at both local or global levels [16].

[17] use the analogy of an iceberg to illustrate the conceptual model known as the Four Levels of Thinking as a framework for systemic interventions.

In this model, events or symptoms (those issues that are easily identifiable) represent only the visible part of the iceberg above the waterline. Most decisions and interventions currently take place at this level, because ‘quick fixes’ (treating the symptoms) appear to be the easiest way out, although they do not provide long lasting solutions. However, at the deeper (fourth) level of thinking that hardly ever comes to the surface are the ‘mental models of individuals and organisations that influence why things work the way they do. Mental models reflect the beliefs, values and assumptions that a person hold ([17]).

Moving to the third level of thinking is a critical step towards understanding how these mental models can be integrated in a systems structure that reveals how the different components are interconnected and affect one another. Thus, systemic structures unravel the intricate lace of relationships in complex systems.

The second level of thinking is to explore and identify the patterns that become apparent when a larger set of events (or data points) become linked to create a ‘history’ of past behaviours or outcomes and to quantify or qualify the relationships between the components of the system as a whole.

The systems thinking paradigm and methodology embrace these four levels of thinking by moving decision-makers and stakeholders from the event level to deeper levels of thinking and providing a systemic framework to deal with complex problems ([17]), such as HWC problem.

4. Conceptual Framework

![Conceptual framework based on system thinking](image-url)

Figure 1. Conceptual framework based on system thinking
Figure 1 shows the conceptual framework model for HWC based on system thinking, which involve interactions and feedbacks within human and natural system. We use the notion of set to describe the model, such as, \{conflict, human\} would have an impact to \{human behaviour\}. Set of \{human characteristic\} could give influence to the set of \{human reaction, human behaviour\}.

Factors that influence human wildlife conflict can be described as follows.

i. Landscape characteristics
ii. Human encroachment
iii. Human population
iv. Wildlife distribution
v. Leuser board strategies
vi. Government policies

In diagram can be shown as in Figure 2.

Figure 2. Conceptual framework of factors for HWC

5. Multi-criteria Decision Making
Nowadays it is quite often in the realm of decision making one encounters with problems which contain more than one objectives. These objectives in particular are independent and may have conflicts to one and another. In terms of mathematical programming, this type of problem belongs to
an approach which is called multi-criteria decision making (MCDM). Practically, goal programming (GP) is the most popular among all MCDM techniques ([18]). An interesting characteristic of GP is that a decision maker is allowed to consider the environmental, organizational, and managerial situation into the model via goal levels and priorities. Mathematically, the lexicographic GP are expressed as follows.

The objective is to minimize deviation from the desired goals which is consistent with the AHP ranking of the alternatives.

$$\text{Minimize } z = \sum_{i=1}^{m} P_{i}(d_{i}^{+} + d_{i}^{-})$$  \hspace{1cm} (1)

Subject to

Goal constraints:
$$\sum_{j=1}^{n} a_{ij}A_{j} - d_{i}^{+} + d_{i}^{-} = b_{i}, \quad \text{for } i = 1, \ldots, m$$  \hspace{1cm} (2)

System constraints:
$$\sum_{j=1}^{n} a_{ij}A_{j} = b_{i}, \quad \text{for } i = m + 1, \ldots, m + k$$  \hspace{1cm} (3)

with $d_{i}^{+}, d_{i}^{-}, A_{j} \geq 0, \quad \text{for } i = 1, \ldots, m; \quad j = 1, \ldots n$  \hspace{1cm} (4)

It can be seen that there are $m$ goals, $k$ system constraints and $n$ decision variables. Where $d_{i}^{+}$ is a deviational variable of overachievement of goal $i$, and $d_{i}^{-}$ is a deviational variable of underachievement of goal $i$.

6. Conclusion

We have focused on conflicts between human and wildlife due to conservation concern, particularly happened at Leuser Landscape. The conflict which threatened human living and crops is necessarily to be managed properly. We consider the HWC as a system, and then we put into the concept of system thinking. The linkages between the whole factors involved are described in the conceptual model framework. In order to mitigate the conflict optimally we will use multi-criteria decision making.

References

[1] Woodroffe, R., Thirgood, S., & Rabinowitz, A. (Eds.). 2005. People and wildlife, conflict or coexistence? Cambridge: Cambridge University Press.
[2] Dickman, A. J., 2010. Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict. Anim. Conserv. 13, pp. 458-466.
[3] Gilleland, A. H., 2010. Human-wildlife conflict across urbanization gradients: Spatial, social, and ecological factors. Graduate Theses and Dissertation. University of South Florida.
[4] Breitenmoser, U., Angst, C., Landry, J-M., Breitenmoser-Wursten, C., Linnell, J.D.C. & Weber, J-M., 2005. Nonlethal techniques for reducing depredation. In People and wildlife: conflict or coexistence?: pp. 49–61. Woodroffe, R., Thirgood, S. & Rabinowitz, A. (Eds). Cambridge: Cambridge University Press.
[5] Muruthi, P., 2005. Human wildlife conflicts: Lessons learned from AWD’s African heartland. AWF working Papers, July 2015, 12p
[6] White, R. M., Fischer, A., Marshall, K., Travis, J. M. J., Webb, T. J., di Falco, S., Redpath, S. M., van der Wal, R., 2009. Developing and integrated conceptual framework to understand biodiversity conflicts. Land Use Policy, 26, pp. 242-253.
[7] Morzillo, A. T., de Beurs, K. M., Martin-Mikle, C. J., 2014. A conceptual framework to evaluate human-wildlife interactions within coupled human and natural systems. Ecology and Society, 19(3), pp. 44.
[8] Messmer, T., 2000. The emergence of human wildlife conflict management: Turning challenges into opportunities. International Bio-deterioration & Biodegradation, 45 (2000) 971102.
[9] Redpath, Young, J., Evely, A., Adams, W. M., Sutherland, W. J., Whitehouse, A., Amar, A., Lambert, R. A., Linnell, J. D. C., Watt, A., & Gutierrez, R. J., 2013. Understanding and managing conservation conflicts. Trends in Ecology and Evolution, 28(2).

[10] Shakeel, T, 2016. Approaches to human-wildlife conflict management in and around Ayubia National Park. Khyber Pakthunkhwa, Pakistan. Discovery, 52(250), pp. 2059-2067.

[11] Redpath, S. M., Arroyo, B. E., Leckie, F. M., Bacon, P., Bayfield, N., Gutierrez, R. J., & Thirgood, S. J., 2004. Using decision modeling with stakeholders to reduce human-wildlife conflict: A raptor-grouse case study. Conservation Biology, 18(2), pp. 1-10.

[12] Thirgood, S., Redpath, S., 2005. Hen harriers and red grouse: the ecology of a conflict. Conserv. Biol., Ser., 9, pp. 192-208.

[13] Mosimane, A. W., McCool, S., Brown, P., & ingrebetson, J., 2013. Using mental model in the analysis of human-wildlife conflict from the perspective of a social-ecological system in Namibia. Fauna & Flora International Oryx, pp. 1-7.

[14] Davies, A. L., Bryce, R., & Redpath, S. M., 2013. Use of multi-criteria decision analysis to address conservation conflicts. Conservation Biology, Vol 00(00), pp. 1-9.

[15] Decker, D. J., & Purdy, K. G., 1988. Toward a concept of wildlife acceptance capacity in wildlife management. Wildlife Society Bulletin, 16, pp. 53–57.

[16] Monat, J. P., & Gannon, T. F., 2015. What is system thinking? A review of selected literature plus recommendations. American Journal of Systems Science, 4(1), pp. 11-26.

[17] Maani, K. E., & Cavana, R. Y., 2007. Systems Thinking, System Dynamic: Managing Change and Complexity (2nd Ed.). Pearson: Prentice Hall.

[18] Lee, S. M., 1972. Goal programming for decision analysis. Aurbach, Philadelphia.