**BIODIVERSITAS**
Volume 25, Number 6, June 2024
Pages: 2463-2477

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250615

# Bird diversity rate as variable of land use change protection scenario using a system dynamics approach

**FEBRI HANDOYO[1,♥], SOEMARNO[2], SUDARTO[2], LUCHMAN HAKIM[3]**
[1]Doctoral Program of Agriculture Faculty, Universitas Brawijaya. Jl. Veteran, Lowokwaru, Malang 65145, East Java, Indonesia. Tel.: +62-341-551611, ♥email: fehandoyo@gmail.com
[2]Faculty of Agriculture, Universitas Brawijaya. Jl. Veteran, Lowokwaru, Malang 65145, East Java, Indonesia
[3]Faculty of Mathematics and Natural Sciences, Universitas Brawijaya. Jl. Veteran, Lowokwaru, Malang 65145, East Java, Indonesia

Manuscript received: 16 December 2023. Revision accepted: 11 June 2024.

**Abstract.** *Handoyo F, Soemarno, Sudarto, Hakim L. 2024. Bird diversity rate as variable of land use change protection scenario using a system dynamics approach. Biodiversitas 25: 2463-2477.* The existence of enclave villages in Bromo Tengger Semeru National Park, East Java, Indonesia raises concerns about land use changes in the conservation areas. This study analyzed the position of bird diversity rate as a variable in system dynamics modeling. Data from the results of the stock flow diagram simulation, which consists of the bird diversity rate variable, along with other variables, are references used for assessing answers regarding efforts to protect conservation areas through several scenarios. The aim of this study was to predict the best scenario for the protection of national park areas that include the bird diversity rate as a variable. Bird species observations at 2 sites found 21 families and 34 species out of 135 total recorded individuals. The diversity index (H') is relatively high, the Evenness Index (E) is relatively evenly distributed between species. The Margallef Richness Index (R) at location 1 is classified as medium and location 2 is classified as low. The simulation results of stock flow diagram model (2015-2050) shows that the national park area, decreased. Measurements of bird diversity rate have also decreased. The best interventions seen in scenario 2 and scenario 3 have a good impact on reducing land use change. Protection of national park areas in scenario 3 can increase bird species diversity rate by up to 76% by implementing important actions in ecosystem improvement.

**Keywords:** Enclave, land protection scenario, nature conservation, stock flow diagram, wildlife

## INTRODUCTION

The management of natural resources in a conservation area with all forms and criteria for space allocation is carried out using a zoning system intended for achieving the sustainability of biodiversity and the balance of their ecosystem (Wei et al. 2020). The challenges faced in the concept of area protection are related to land use by communities around conservation and protected areas (Degele 2023). The activities of local communities in using land in conservation areas have the potential to cause problems in area management and problems in maintaining biodiversity (Andonegi et al. 2021). Obstacles in protecting conservation areas can be related to encroachment, inappropriate land use, habitat fragmentation, and decline of biodiversity (Zakkak et al. 2013; McCarthy et al. 2021). Efforts to protect conservation areas need to pay attention to the management policies and the impact of the activities of the surrounding community (Blicharska et al. 2020). The emergence of edge effects is a phenomenon that cannot be avoided due to the activities of the surrounding community (Kavwele et al. 2022). Agricultural expansion into forest areas causes loss of natural vegetation, environmental damage, wider social impacts, and landscape fragmentation that seriously threaten biodiversity (Levers et al. 2021; Ma et al. 2023). Fragmentation causes habitat damage and loss of certain species, which will result in the disruption of food chains and food webs (Pires et al. 2023).

Efforts to protect conservation areas are required, so that disruptions in land use change and decline in biodiversity can be handled properly (Huang et al. 2018). Developing the concept of protection in the management of conservation areas requires accurate, up-to-date data regarding the state of biodiversity, the land suitability, and the activities of the surrounding community (Ioki et al. 2019; Ezquerro et al. 2023). The existence of the enclave and all its community activities raises concerns about land conversion in the national park area and the decline in bird diversity in Bromo Tengger Semeru National Park (TNBTS), East Java, Indonesia. High demand for agricultural land, increasing population, and encroachment are social dynamics that cannot be avoided. The aim of this study was to predict the best scenario for the protection of national park areas that include the bird diversity rate as a variable. Conservation efforts in the TNBTS area near the two enclave villages are also closely related to wildlife conservation, especially the existence of birds.

The research area in the TNBTS area is an important area for Important Bird Areas (IBA) birds, especially in habitats such as forest, grassland, and lakes (Ranu Pani and Ranu Regulo). This area is also included in the scope of the Endemic Birds Area/EBA status for the island of Java with one of the threatened species, namely the Javan hawk eagle (*Nisaetus bartelsi* Stresemann 1924), and several other endemic species such as Javan hanging-parrot (*Loriculus pusillus* G.R.Gray 1859) and Javan frogmouth (*Batrachostomus* *javensis* Horsfield 1821) (BirdLife International 2004). The existence of birds in national park areas is one of the important elements that form the physical structure of social phenomena that occur in natural resource utilization patterns. The system dynamics model is built from several interrelated elements to form a structure, including the ecological condition, the bird diversity rate, the socio-economics of the village community, policies, and impacts.

The complexity of forest ecosystem problems and the social systems of surrounding communities requires system thinking as analytical approach and simulation to review and understand how the system can work (Horigue et al. 2023). System dynamics is an approach to understanding the behavior of complex non-linear systems over time using several variables based on structure and feedback analysis, including model simulations with equations (Naugle et al. 2024). Complex and dynamic environmental and social problems require dynamic system simulations using differential equations to obtain predictive assessment information (Karami et al. 2017).

The application of system dynamics with the use of stock and flow diagrams allows to encourage models to run various scenarios where stock is an entity that accumulates or depletes over time, while flow is the rate of change of a stock presented by differential equations (Barbrook and Penn 2022). If systems in national park areas can be modeled, then management policy scenarios for the protection of national park areas and predictions of bird diversity rate over a certain period can be done through the software application of system dynamics. Systems dynamics builds computer simulation models to confirm that the structures that have been built can lead to the observed behavior to test the effects of alternative policies over time (Holland et al. 2023).

## MATERIALS AND METHODS

### Study area

This research was carried out in the TNBTS area and two enclave villages which were delineated into areas of interest, East Java, Indonesia (7°57'46,786"S-8°1'27,608"S; 112°52'21,173"E-112°57'17,834"E). The observation area (Figure 1) consists of an enclave village, a national park area and bird observation points. The enclave village of Ngadas is located in the Sub-district of Poncokusumo, Malang and Ranupani Village is in the Sub-district of Senduro, Lumajang, East Java, Indonesia. The national park management zone area around the enclave village is part of the field observations, including: traditional zone (ZTr), wilderness zone (ZRi), and utilization zone (ZP). The traditional zone was chosen as part of the observation area because the zone is directly adjacent to the enclave village.

Likewise, the wilderness zone and utilization zone are also directly adjacent to enclave villages and traditional zones. According to the Minister of Environment and Forestry Regulation/*Permen LHK* (2015) Number P.76/Menlhk-Setjen/2015) the wilderness zone has the function of preserving and supporting the core zone of the national park, while the utilization zone has the function of developing natural tourism and environmental services. A traditional zone is an area that meets the criteria for being a forest zone and a utilization zone which refers to the conservation regulations of ministerial decree P.76/Menlhk-Setjen/2015, where there is direct interaction between the enclave village community and the traditional zone.

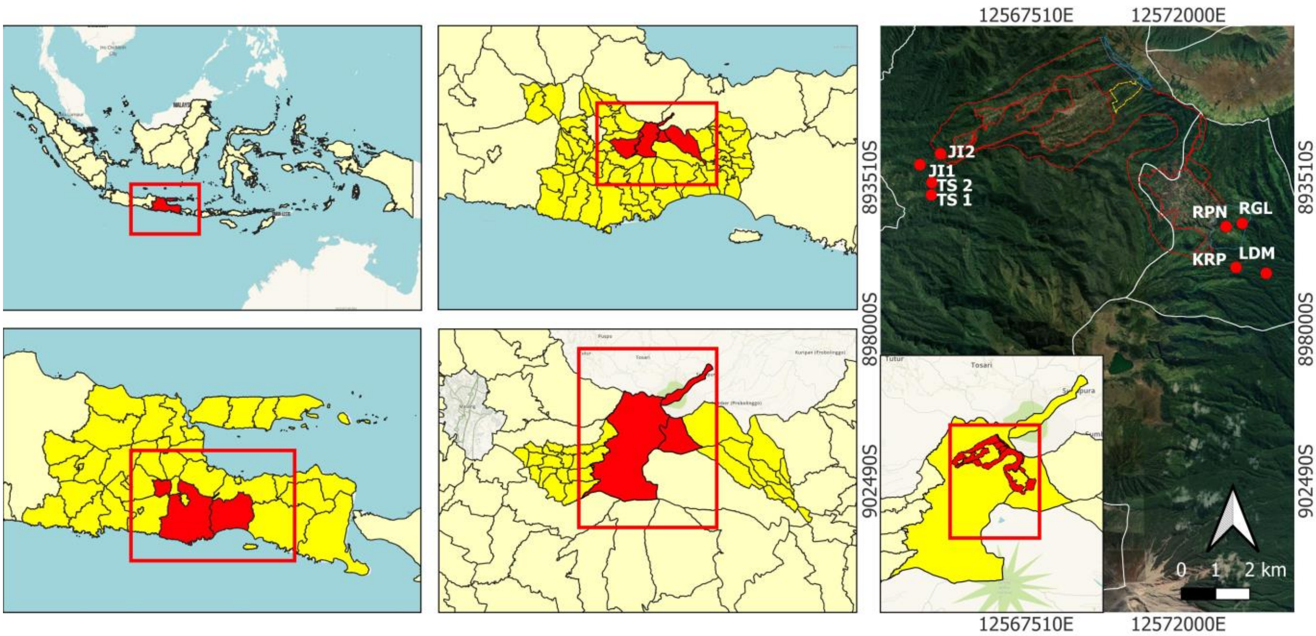


**Figure 1.** Location of research area (AOI) consisting of enclave villages (Ngadas: 373.2 Ha, Ranupani: 265.3 Ha) and TNBTS areas, East Java, Indonesia. ZTr (red dash line): 1,402.3 Ha, ZRi (yellow dash line): 40.0 Ha, ZP (blue dash line): 155.5 Ha. Count point for bird observations is at location 1 (TS1, TS2, JI1, JI2) and location 2 (LDM, KRP, RPN, RGL)

This ministerial decree is also the basis for determining the boundaries of the Area of Interest (AOI) in this research which consists of enclave villages, ZTr, ZRi, and Zp (Figure 1). Bird watching was carried out in the TNBTS area adjacent to the enclave villages. The positions of the bird observation point are inside AOI and outside the AOI area, where each selected observation points are still in a national park area with relatively well-preserved tree vegetation. The distance between observation points is at least more than 50 meters and the observation radius at 1 count point is around 30 meter. Consideration in selecting observation points is also made in areas that have good land cover and vegetation conditions as places for bird activity.

Based on previous research, bird observations were carried out and concentrated at points that were expected to be places where many bird species were likely to be found. Bird watching points in the TNBTS area close to Ngadas Village (Location 1) are in the Coban Trisula area (TS1, TS2) and the area leading to the village of Jarak Ijio (JI1, JI2) which have an altitude of 1,383 - 1,561 meters above sea level (asl). Meanwhile, observation points near Ranupani Village (Location 2) are in the Ledok Malang (LDM), Krepelan (KRP), Ranu Pani Lake (RPN) and Regulo Lake (RGL) areas which have an altitude of 1,958-2,102 meters asl. The observation areas in this study are in two terrestrial ecosystem zones, where location 1 is in the sub montane zone (750-1,500 m asl) and location 2 is in the montane zone (1,500-2,400 m asl).

The ecosystem type of the TNBTS area at location 1 (near Ngadas Village) is a tropical mountain rainforest with a fairly high level of diversity and density of plant species. Meanwhile, location 2 (near Ranupani Village) is classified as a secondary forest type where the diversity of plant species has begun to decrease (BBTNBTS 2015). The research observation area around two enclave villages (Ngadas and Ranupani) have climate type D based on the Schmidt and Ferguson classification where most of the TNBTS areas have cold temperatures. The lowest temperature at the observation site can reach 3-6°C and the maximum temperature ranges from 20-23°C.

**Procedures**

This research requires field observation data and spatial data for system analysis of natural resource utilization patterns. Field observation data were obtained from observations of bird species, their biophysical conditions, and the socio-economic conditions of the enclave village community. Meanwhile, spatial data are data resulting from map processing over a certain period which is compared with actual current conditions. Spatial data processing produces important tabular data that describes changes in land conditions from the past to land conditions today. The data represent phenomena and patterns that occur in national park areas and in enclave villages. Information is collected as research data and then identified to clarify the scope of the problem. A phenomenon formed through a number of components and the pattern of relationships between these components is seen as a structure. A systematic structure reveals how patterns of data are interconnected and influence each other. Furthermore, this structure will become a framework which can be visualized through a casual modeling approach or explained as a casual loop diagram (Banson et al. 2020).

The results of the framework from various detailed information produce several data changes over a certain period of time both qualitatively and quantitatively as a behavior in the system. Quantitative changes in the system need to be made into a simulation model through structural modeling of Stock Flow Diagrams. Stock and flow diagrams are the most common steps in model building simulations because they help determine the types of variables that are important in causing behavior (Qiu et al. 2015). The creation of simulations using stock flow diagrams in this study was carried out using System dynamics software, Vensim PLE 8.2.1. The results of processing field data and spatial data then become variable data which is input into the system dynamics software application. The output from processing several of these variable data is predictive data related to land conversion in national park areas in the future.

*Birds data collection*

The diversity of bird species is one of the variables needed in the data analysis process through modeling of system dynamics. Data collection begins with a survey to make observations at several count points. Observations were carried out using a concentrated counting method (concentration count) where the selection point for bird counting was determined according to the concentration of birds that were highly active. The data needed for bird observations in the field are the types of birds found and the total number of individuals that have been counted in 3 repetitions on different days. Data on the number of individuals from different days is then pooled based on the observation location (loc1 or loc2). The number of individuals of each species from the two observation locations is the total number of individuals from all bird observation points.

Meanwhile, the encounter probability value of finding birds in all locations is obtained from the total number of individuals divided by the total number of observation times (hours). The materials used for species identification are The Field Guide Books for Bird Identification by MacKinnon et al. (2010), the book on observations from TNBTS by Prasetya et al. (2018), while the nomenclature and sequence follow the book of Birds of The Indonesian Archipelago by Eaton et al. (2016). Bird observations were carried out in the morning at 06.30 WIB (GMT+7) until 10.30 WIB (GMT+7). Bird observations were conducted during the dry season in October 2022 using the standard point count method (Bibby et al. 2000). The time chosen for observing birds was in the morning because more birds are found foraging common in the morning than in the afternoon (Stockwell et al. 2021). The tools needed for bird identification are binoculars and a Canon EOS 70D Digital Single Lens Reflex (DSLR) camera. Meanwhile, the position of observation points is recorded using a Global Positioning System (GPS) tool.

The position of the bird observation point (Figure 1) was chosen and concentrated in a location that is expected to be a place of activity with the possibility to find particular species of birds in TNBTS, including endemic bird species (Prasetya and Siswoyo 2018). Each bird encountered is recorded and its species are identified, then the probability of encounter is calculated from the total number of individuals per total hour of observation (Kaban et al. 2017). Differences in the number and types of birds encountered between location 1 and location 2 were calculated based on the species diversity index, evenness index, and species richness index.

The Shannon-Wiener is used to estimate the diversity of bird species between two observation locations and the Margalef Species Richness Index (R) to estimate bird species richness (Magurran 2004). The evenness index (E') referring to the Pielow evenness index formula (Ludwig and Reynolds 1988) is used to estimate the evenness of species richness between habitat types (Krebs 1985; Magurran 2004). Diversity of birds was calculated using Shannon-Wiener Diversity Index (H') as follow: $H' = -\sum pi. Ln\ pi$, where ‘pi’ is proportion of individuals of species, Ln is natural logarithm. If $H'<1.5$ the diversity is categorized as low, values of 1.5 to 3.5 are categorized as moderate, and values> 3.5 indicate high diversity. The Margalef species richness index (R) was presented as follow : $R=S-1/LnN$, where S is number of species, N is total number of individuals observed.

The Margalef’s index able to respond to species differences and has high sensitivity to estimate the functional richness of habitats (Bhusal and Sneha 2021; Novriyanti et al. 2021). Category determination of the Margalef Species Richness Index (R); if R< 3.5, the richness is defined low; if the R value of 3.5 to 5, the species richness are categorized as moderate; and if R>5, the species richness are categorized high. Afterward, the evenness index can be represented by Pielou's evenness index (E) was was presented as follow : $E = H'/Ln\ S$. The E value ranges from 0 to 1, where a higher value indicates a higher level of evenness, which means that the maximum evenness is the value of E=1.

*Natural resource utilization patterns*

The pattern of natural resource utilization in this research is the result of our understanding of a phenomenon that is formed by several components that are interconnected to form a systematic structure. A phenomenon whose structure is already known can be perceived as a system. Systematic structure is the foundation for the formation of patterns and events (Monat and Gannon 2023). Systematic structures are often difficult to see, where we only see the events (such as in The Iceberg phenomenon), and make it the basis for determining decision making. In fact, events are only the result of a structure. Therefore, decisions made based on events will not solve a problem. For this reason, we need to create an approach as a framework for thinking by creating simulations and modeling with system dynamics by understanding its structure (Shin et al. 2022). Structure is a phenomenon formed from interrelated components (Sterman 2002).

Component data recognized in the pattern of natural resource utilization activities include: population, village community life, land in enclave villages and land in national park areas, impacts, and policies. Population data comes from BPS data collection and monographs from each enclave village. Land use area was obtained from field observations and high-resolution map delineation using Google Earth. Raster data from search results from Google Earth is then processed into vector data via ArcGis application software. The socio-economic life of village communities related to the allocation of land use activities was obtained from interviews with respondents. The sample selection was carried out deliberately (purposive sampling) by selecting people that are feasible to represent the information needed as key informants (Tongco 2007). The phenomenon of land use and the causality relationships that occur were explored through interviews using the in-depth interview method (Boyce and Neale 2006).

The impact of natural resource utilization activities is observed from environmental damage, Land Use and Land Cover (LULC) in national park areas. Environmental damage related to village community activities is observed from changes in the water bodies area in Ranu Pani Lake from 2004 to 2022. Another impact observed was LULC changes in the national park area which caused landscape changes and disruption of wild life. Changes in LULC area within the national park area are measured by LULC changes from 1980 to 2022 using Google Earth high resolution maps. Meanwhile, the wildlife parameter, one of the important components observed in this research, is the bird diversity rate. The policy of national park management regarding regional land use is also an important part in preparing causality relationships for all observed components and implementing modeling in system dynamics applications.

*Causal Loop Diagram (CLD)*

Causal loop diagrams are created to show the existence of variable relationships in a system. In the CLD image, there are several cause and effect relationships that influence national park land use. The main variables are population, agricultural land, national park land and residential land. Population is the main variable because the more the population in a place increases, the higher the number of increases and the rate of population growth. The increase in population will have an impact on residential land or more precisely on housing needs per capita. The higher the population, the need for housing increases. The increase in population also has an impact on the standard of living, where in enclave villages the majority of jobs are as farmers. So when the population increases, the number of farmers increases to meet living needs (Figure 2). Starting from the population size, it can have an impact on meeting the increasing residential and agricultural needs. The higher the need for housing, the higher the rate of conversion of agricultural land into residential land.

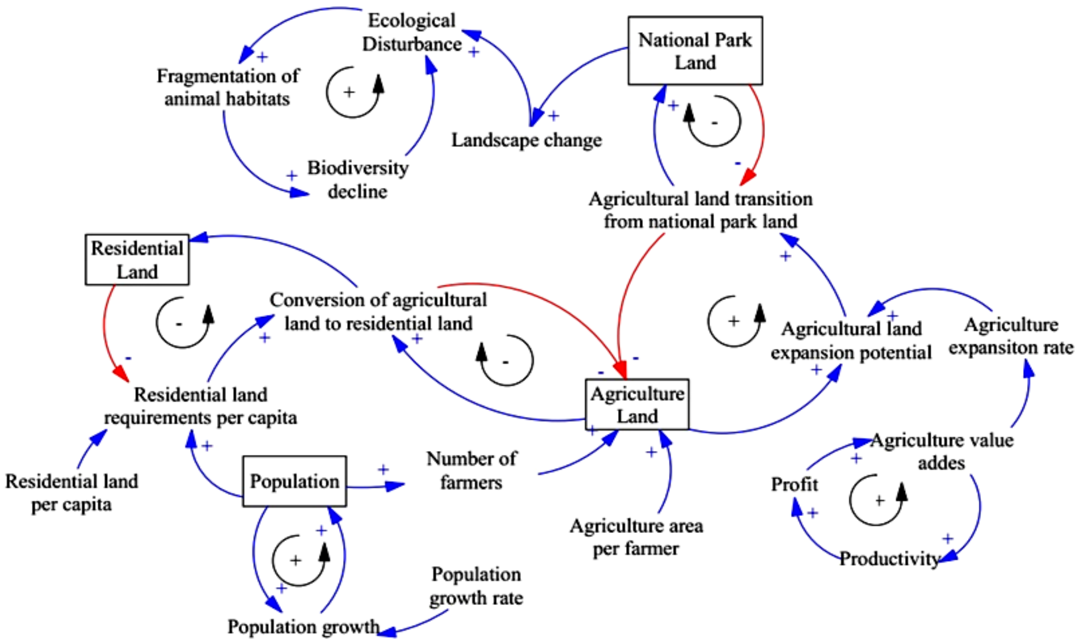


**Figure 2**. Causal Loop Diagram (CLD) of land use changes in Bromo Tengger Semeru National Parks (TNBTS), East Java, Indonesia

In addition, with the increasing rate of residential land conservation, farmers usually carry out encroachment to meet the need for agricultural land. So the higher the number of farmers and the rate of residential land conversion, the need for agricultural land will increase, which is fulfilled by encroaching on national park land. The transition of national park land is currently increasing due to the increasing demand of enclave village communities for agricultural land and residential land. So apart from reducing national park land, environmentally unfriendly encroachment will result in changes to the national park landscape. If the changes in the landscape of this national park gets higher, it could result in a decrease in biodiversity and ecological disruption.

**Data analysis**

*Stock flow diagram*

Analysis was carried out on several data components from the results of spatial data processing, field data, interviews, and secondary data. The application of modeling is made by synthesizing the research component data until a systematic structure is formed. This structure reveals a pattern of relationships between several components that influence each other. Identification of problems is needed to obtain a formulation of causality thinking which can be described through a casual loop diagram (Banson et al. 2020). A systematic structure that explains causality relationships in complex systems becomes a reference for creating models and simulations using Stock Flow Diagrams (SFD). Stock (Level) is the basis for generating behavior in a system. The SFD model in this research consists of several stock data which have flow variables, constants, and auxiliaries. The stock variables in the SFD model used are national park land, agricultural land, residential areas, and local population. Stock variable is a variable with initial data as the initial data or stock that is measured at a certain point in time (Lane 2000).

Meanwhile, flow variables (rate variables) such as bird diversity rate are quantities measured per unit of time. Rate variable can also be interpreted as a policy structure that explains a decision (action) based on the information available in the system (Schoenenberger et al. 2021). The model that has been formed is then verified and validated to determine the credibility of the model in representing the actual situation. Simulations were carried out on verified and validated models using Vensim PLE 8.2.1 software. The results (output) of the simulation are in the form of graphs describing real (existing) conditions that are occurring currently and predictions of the value at a point in the future (point prediction). Analysis is needed to explain the immensity of changes that will occur in the future and what strategies are needed. Scenario development is a way to create alternative policies by changing parameters that have an influence on the model or referred to as behavior prediction (Dietz et al. 2023).

The parameters that will be simulated in the model in this research include limiting the conversion of national park land, increasing agricultural productivity, and improving the ecosystem to preserve wild life, especially bird life. Policy analysis is carried out by comparing data from simulations of real conditions (existing) with several simulation data from several scenarios. Comparison and reconciliation of data in this research is needed to reduce the gap between existing conditions and the ideal conditions expected through national park management policies.

*Model assumtions and scenario*

The system modeling was built after obtaining a conceptual model formulation by identifying all components and their relationships with system dynamics software (Vensim PLE 8.2.1). Assumptions in system dynamics models need to be used with the availability of proper and relevant information in order to describe the desired system. These assumptions can influence scenarios (policies) because they can regulate how the system is built, interacted and estimated according to the expected time. The land use model in national park (TNBTS) areas in natural resource utilization patterns will experience very dynamic changes in the future. Pressure on the existence of national park areas due to changes in Land Use and Land Cover (LULC) can have a negative impact on ecosystems and their conservation functions.

Therefore, in the existing system model, several assumptions will be made in scenarios that allow reducing TNBTS land use and taking into account the sustainability of life of the enclave villages community. scenarios that allow reducing TNBTS land use and taking into account the sustainability of life of the enclave villages community. This research uses 4 assumptions applied to the model development scenario, where these assumptions are the determining factors in improving existing conditions (Table 1). The assumptions applied in building scenarios for preventing land use changes in national park areas consist of internal and external factors. Internal factors relate to the management of protecting national park areas which includes limiting land conversion such as encroachment activities (assumption 1) and improving the ecosystem (assumption 4).

Meanwhile, external factors are efforts to protect land through policies outside national park management, such as limiting the change of agricultural land to residential land (assumption 2) and increasing agricultural productivity (assumption 3). Assumptions in scenarios 1, 2 and 3 are implemented by changing the variable values through trial and error data. Only use 1 or more assumptions can be used for applying changes in variables (assumptions) in a scenario. The percentage change in the assumed value can be increased or decreased according to the ideal conditions that have been previously projected.

The assumptions (Table 1) applied to each scenario are different, where the assumption in scenario 1 is limiting the national park land conversion to agricultural land by 15%. In scenario 2, the conversion of national park land into agricultural land is limited to 15%, and the conversion of agricultural land to residential areas is limited to 10%, and the increase in agricultural productivity is 10%. Meanwhile, in scenario 3, restrictions on conversion of national park land to agricultural land decrease by 10%, restrictions on conversion of agricultural land for conversion to residential areas by 10%, increase in agricultural productivity by 30%, and improvement of the ecosystem on TNBTS land by 30%. The model was run with these 3 scenarios having different variations of driving variables such as the conversion of national park land to agricultural land and agricultural land to residential area. Restricting conversion of functions, increasing agricultural productivity, and improving the ecosystem are possible variables to become driving factors in accordance with the expected conditions.

## RESULTS AND DISCUSSION

### Bird species diversity

Observations of birds at the research location were differentiated based on the position of the counting point in the enclave village. The types of tree vegetation that were part of bird activity were also observed, where at location 1 (near Ngadas Village) the Great Malay bean (*Engelhardia spicata* Lesch. ex Blume), Chinese mahogany (*Toona sinensis* (A.Juss.) M.Roem.), charcoal-tree (*Trema orientale* (L.) Blume), mountain ru (*Casuariana junghuhniana* Miq.), and other tree species were often found. Meanwhile, the types of tree vegetation found in location 2 (near Ranupani Village) include Pampung (*Macropanax dispermus* (Blume) Kuntze), Sunda oak (*Lithocarpus sundaicus* (Blume) Rehder), mountain ru (*C. junghuhniana*), Great Malay bean (*E. spicata*), and early green wattle (*Acacia decurrens* Willd). There are differences in the types of tree vegetation at the bird watching locations at location 1 and location 2 due to the ecosystem zone and its altitude. The differences in habitat conditions of the two locations will certainly determine the type of bird and the number of individuals active in the area. The results of bird observations in two locations were 21 families, 34 species and 135 individuals of birds (Table 2). The positions of bird counting points are inside and outside the AOI, including areas close to many community activities such as farming activities, nature tourism, and some areas are also used as passageways for various types of vehicles. Conservation status based on the IUCN Red List of Threatened Species identified 1 bird species with endangered (EN) status and 1 species with near threatened (NT) status. In addition, 9 species were found to be protected by regulations of the Minister of Environment and Forestry of the Republic of Indonesia (Permen LHK No. P.106/Menlhk/Setjen/Kum.1/12/2018) and 6 species were classified as endemic according to the Endemic Bird Area (EBA) by BirdLife International (2023).

**Table 1.** Assumptions used to create scenarios

| Scenario | Assumption 1 | Assumption 2 | Assumption 3 | Assumption 4 |
|---|---|---|---|---|
| Scenario 1 | 15% | - | - | - |
| Scenario 2 | 15% | 10 % | 10% | - |
| Scenario 3 | 10% | 10% | 30 % | 30 % |

Notes: Assumption 1: Limitation of land conversion; Assumption 2: Limitation of agricultural land conversion into residential areas; Assumption 3: Increase in productivity; Assumption 4: Improvement of ecosystems

**Table 2.** List of bird species encounter at location 1 (Loc1) and location 2 (Loc2) with conservation status by IUCN, regulations of The Minister of Environment and Forestry, and Endemic Birds Area (EBA)

| Family | Scientific name | Common name | Num. of Individuals | | | Indv/hr | Conservation status | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Loc1 | Loc2 | Total | | IUCN | LHK | End |
| Accipitridae | *Nisaetus limnaeetus* | Changeable Hawk Eagle | 1 | | 1 | 0.04 | LC | P | |
| Accipitridae | *Ictinaetus malaiensis* | Black Eagle | 1 | 1 | 2 | 0.08 | LC | P | |
| Accipitridae | *Nisaetus bartelsi* | Javan Hawk Eagle | 1 | | 1 | 0.04 | EN | P | E |
| Accipitridae | *Lophotriorchis kienerii* | Rufous-bellied Eagle | | 1 | 1 | 0.04 | LC | P | |
| Alcedinidae | *Todiramphus chloris* | Collared Kingfisher | 3 | | 3 | 0.13 | LC | P | |
| Apodidae | *Collocalia linchi* | Linchi Swiftlet | 37 | | 37 | 1.54 | LC | UNP | |
| Cettidae | *Horornis vulcanius* | Sunda Bush Warbler | 2 | 4 | 6 | 0.25 | LC | UNP | |
| Cisticolidae | *Orthotomus sepium* | Javan Tailorbird | 2 | | 2 | 0.08 | LC | UNP | |
| Columbidae | *Macropygia ruficeps* | Little Cuckoo Dove | 1 | | 1 | 0.04 | LC | UNP | |
| Cuculidae | *Cuculus saturatus* | Himalayan Cuckoo | 1 | | 1 | 0.04 | LC | UNP | |
| Cuculidae | *Cacomantis sepulclaris* | Sunda Brush Cuckoo | | 1 | 1 | 0.04 | LC | UNP | |
| Dicaediae | *Dicaeum sanguinolentum* | Javan Flowerpecker | | 7 | 7 | 0.29 | LC | UNP | |
| Falconidae | *Falco peregrinus* | Peregrine Falcon | | 1 | 1 | 0.04 | LC | P | |
| Locustellidae | *Locustella montis* | Sunda Grashopper Warbler | | 2 | 2 | 0.08 | LC | UNP | |
| Megalaimidae | *Psilopogon armillaris* | Flame-fronted Barbet | 3 | | 3 | 0.13 | LC | P | E |
| Megalaimidae | *Psilopogon haemacephalus roseus* | Coppersmith Barbet | 2 | | 2 | 0.08 | LC | UNP | |
| Muscicapidae | *Ficedula westermanni* | Little Pied Flycatcher | ` | 1 | 5 | 0.21 | LC | UNP | |
| Muscicapidae | *Eumyias indigo* | Indigo Warbling-flycatcher | 1 | | 1 | 0.04 | LC | UNP | E |
| Muscicapidae | *Enicurus leschenaulti* | Javan Forktail | 1 | | 1 | 0.04 | LC | UNP | |
| Muscicapidae | *Brachypteryx leucophrys* | Lesser Shortwing | | 3 | 3 | 0.13 | LC | UNP | |
| Pnoepygidae | *Pnoepyga pusilla* | Pygmy Cupwing | 5 | 6 | 11 | 0.46 | LC | UNP | |
| Psittacidae | *Loriculus pusillus* | Javan Hanging Parrot | 2 | | 2 | 0.08 | NT | P | E |
| Pycnonotidae | *Pycnonotus aurigaster* | Sooty-headed Bulbul | 6 | | 6 | 0.25 | LC | UNP | |
| Pycnonotidae | *Pycnonotus analis* | Sunda Yellow-vented Bulbul | 2 | | 2 | 0.08 | LC | UNP | |
| Phasianidae | *Gallus varius* | Green Junglefowl | | 1 | 1 | 0.04 | LC | UNP | |
| Phylloscopidae | *Seicercus trivirgatus* | Mountain Leaf Warbler | | 2 | 2 | 0.08 | LC | UNP | |
| Sturnidae | *Aplonis panayensis* | Asian Glossy Starling | 1 | | 1 | 0.04 | LC | UNP | |
| Timaliidae | *Pomatorhinus montanus* | Javan Scimitar Babbler | 1 | 1 | 2 | 0.08 | LC | UNP | |
| Timaliidae | *Cyanoderma melanothorax* | Crescent-chested Babbler | 8 | | 8 | 0.33 | LC | P | E |
| Turdidae | *Turdus poliocephalus* | Island Thrush | | 2 | 2 | 0.08 | LC | UNP | |
| Turdidae | *Zoothera horsfieldi* | Horsfield's Thrush | | 2 | 2 | 0.08 | LC | UNP | |
| Vireonidae | *Pteruthius flaviscapis* | Pied Shrike-vireo | 4 | | 4 | 0.17 | LC | UNP | |
| Zosteropidae | *Heleia javanica* | Javan Heleia | 3 | 5 | 8 | 0.33 | LC | UNP | E |
| Zosteropidae | *Zosterops montanus* | Mountain White-eye | | 3 | 3 | 0.13 | LC | UNP | |

Note: Indv/Hr: Encounter Probability (individuals/hours); Based on IUCN: LC: Least Concern; EN: Endangered; NT: Near Threatened; Based on LHK: protected by Permen LHK No. P.106/Menlhk/Setjen/Kum.1/12/2018: P: Protected; UNP: Unprotected; End: Endemic

The existence of the Javan Hawk Eagle at the observation location, based on its conservation status, is a species with the highest level of protection as well as being classified as an endemic species. The results of bird species data processing (Table 3) show that the value of the Shannon-Wiener diversity index (H') at location 1 (H'=2.4) and location 2 (H'=2.6). The H index value at both locations is almost the same, belonging to the medium diversity criteria (H'=1.5 - 3.5). The Diversity Index at both locations is a quantitative measure of the differences in species observed in a community. Other indices also serve as statistical representations of Shannon-Wiener diversity in the aspects of evenness (evenness index) and richness (R index). The Pielou evenness index can also be used to analyze the diversity of bird species where the index values at location 1 (E=0.8) and location 2 (E=1.2) are classified as high evenness criteria (E>0.6). The evenness index at both observation locations illustrates the presence of an evenly distributed number of individuals of a species where each species has almost the same contribution to the total community diversity.

The evenness index value in location 1 appears to be lower than the index value in location 2, which means that the presence of species in location 2 is more evenly distributed compared to location 1. This indicates that some species in location 1 have higher species dominance (dominant tendencies) compared to location 2. Meanwhile, the Margalef species richness index (R) is another index that can be used to measure the richness of species included in the context of the research area (Poudel et al. 2021). At location 1, the species richness index value (R= 4.9) is classified as medium criteria (R= 3.5-5). Meanwhile, at location 2, the species richness value (R=2.1) is classified as low (R<3.5). The species richness index value describes that location 1 has a higher number of species compared to location 2. However, a higher R index value in one observation area does not necessarily indicate a healthy ecosystem compared to other observation areas (Daly et al. 2018). This situation can be reversed if in the ecosystem there are other bird species that are not resident, such as migratory birds, birds that come massively in certain seasons.Migratory birds that have been found in the observation area are more often found in Ranu Pani Lake and Ngadas Village (Prasetya et al. 2018).

In the observation area, some bird species that have a high cruising range were found, such as birds from the Accipitridae, Falconidae, and several migrant species. The existence of the TNBTS conservation area is an important area for their activities to stop, rest, search for prey, settle, and nest. Good habitat conditions are an important factor for birds to do various activities. The condition of vegetation and trees that are still intact are important habitat (patches) for birds to do their activities. The loss of small forest areas without trees and other important vegetation can cause a large percentage of extinctions (MacKinnon et al. 2010). Efforts to maintain the condition of bird habitats from damage and land conversion are a big challenge for the national park management.

**Land use change and land degradation**

Forest conditions, land cover, and land use in the TNBTS conservation area around the enclave village have experienced changes from year to year which could threaten the existence of bird habitat there. The variables used in this research include changes in the size of the national park area around the enclave and changes in lake water bodies (shallowing) due to agricultural activities. Searching and processing spatial data from year to year shows that there have been changes in land use and land cover (LULC) in the TNBTS area (Figure 3). Observations in the field show that most land changes are caused by agricultural activities by communities around the enclave villages. Land in the national park area was converted into agricultural land. Changes in land function due to land conversion in national park around Ngadas Village in Figure 3 reached a total area of 115.1 Ha which includes LULC1 in 2015 (49.8 Ha), LULC2 in 2021 (34.7 Ha) and LULC3 in 2022 (30.61 Ha). Meanwhile, the area of national park land conversion around Ranu Pani Village reached a total area of 11.9 Ha, which includes LULC4 in 1980 (57.4 Ha) and LULC5 in 2022 (54.5 Ha). The reduction of forests, trees, and land cover for bird activity due to land conversion is a growing concern for the presence of birds in mountain forests. The mountain forests on the island of Java are the peak bird habitat where graphically there is a decrease in the number of bird species as the hill or mountain zone increases above sea level (MacKinnon et al. 2010). The increase in population and increasing living needs of rural communities will also increase pressure on the use of natural resources. The need for agricultural land to increase agricultural production then results in the conversion of national park land into agricultural land. On the other hand, agricultural activities carried out by village communities have also had an impact on the environment, such as the shallowing of Ranu Pani Lake and the eutrophication of the Giant Salvinia aquatic plant (*Salvinia molesta* D.S.Mitch). Soil material and fertilizer from farming activities cause the lake's water body to change from year to year (Figure 4).

**Table 3.** Summary of bird observation data at research area (location 1 and location 2)

| Variables | Location 1 | Location 2 |
|---|---|---|
| Birds Family | 16 | 13 |
| Birds Species | 23 | 17 |
| Number of individual (Indv/hr) | 7.7 | 3.6 |
| Diversity index (H’) | 2.4 | 2.6 |
| Evennes index (E) | 0.8 | 1.2 |
| Richness index (R) | 4.9 | 2.1 |
| Altitude (asl;meters) | 1,383-1,561 | 1,958-2,102 |
| Count point | TS1, TS2, JI1, JI2. | LDM, KRP, RPN, RGL |
| Enclave village nearby | Ngadas | Ranupani |
| Terrestrial zone | Sub montane | Montane |

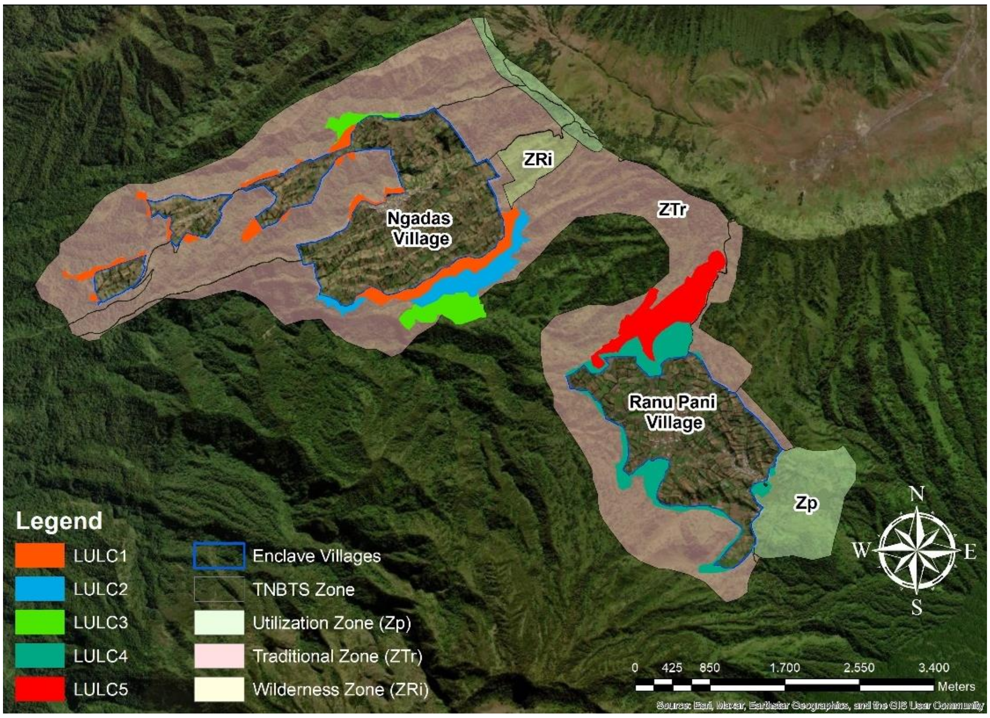


**Figure 3.** Land use and land cover (LULC) changes in the TNBTS area, East Java, Indonesia around the enclave village

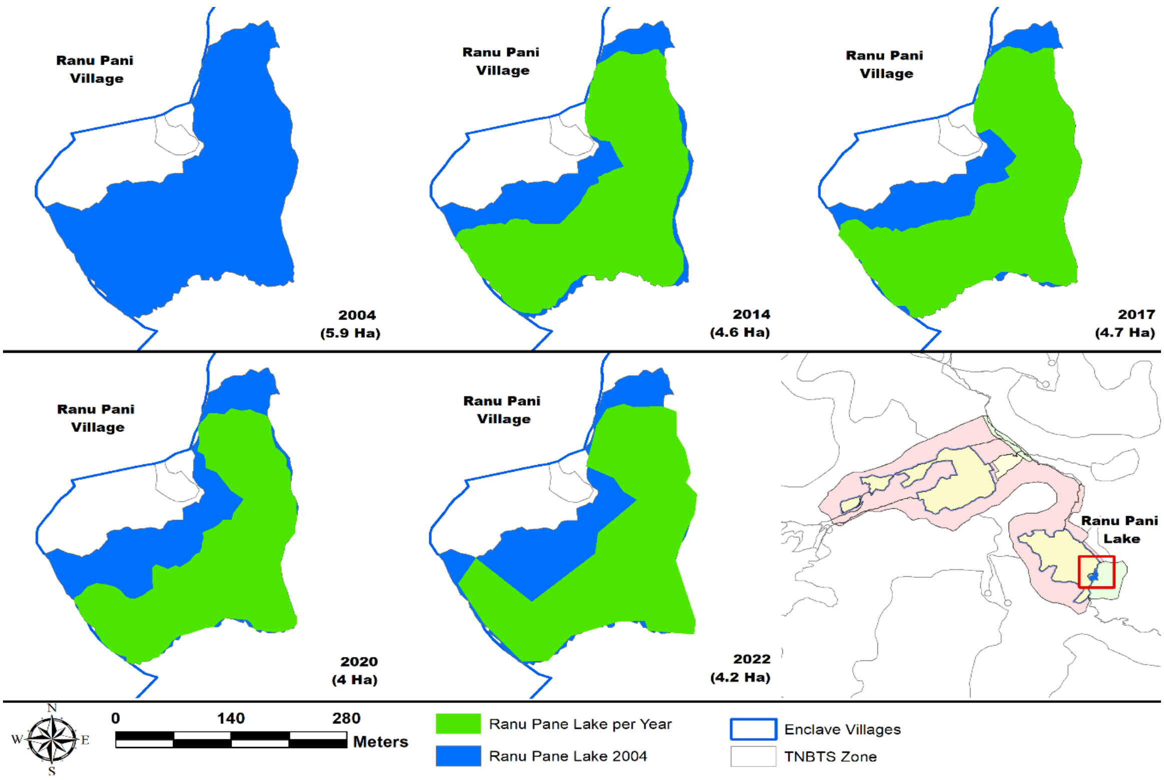


**Figure 4.** Changes in the water body area of Lake Ranu Pani, East Java, Indonesia from 2004 to 2022

Spatial changes in water bodies were revealed from 2004 to 2022. In 2004, the condition of the lake had not experienced shallowing, where the water body had an area of 5.9 Ha. The recorded area of water bodies in recent years shows a change in the extent of water bodies of up to 4.2 Ha in 2022 or a decrease of 28.8%. Data on changes in the water body of Ranu Pani Lake to land (Figure 3) caused by shallowing due to agricultural activities are a growing concern as it could disrupt the habitat and activities of birds around the lake. Ranu Pani Lake is also occasionally a place of activity for sedentary birds. In observations of bird species several years ago (Prasetya and Siswoyo 2018), sedentary birds like Cinnamon Bittern (*Ixobrychus cinnamomeus* Gmelin 1789), White-breasted Waterhen (*Amaurornis phoenicurus* Pennant 1769)) and migratory bird species such as Common Sandpiper (*Actitis hypoleucos* Linnaeus 1758) were still frequently found. However, habitant and migratory birds are currently rarely seen. Observations of bird species in this study also did not find these types of birds. Changes in vegetation and water bodies can act as a barrier for birds to do activities in the lake. Exploitation due to human activities is the cause of wetland degradation and lake shallowing. Lake impoundment changes the habitat of waterbirds which in turn can change the diversity of waterbirds in shallow lakes (Xinjian et al. 2020).

**National park area protection scenario**

Bird observation data, land conversion data, and land degradation data are some of the variable data (flow variables) whose input and output data flows are related to stock variables. In this study, stock data is a variable with initial data from national park land, agricultural land, residential areas, and population of enclave village communities. The data is then measured up to a certain point in time which will also influence the variable data. Measurement of data on natural resource utilization and land use variables into a system dynamic is limited to the defined AOI. The magnitude of land use change (LULC) and environmental degradation such as shallowing of lakes in national park areas is measured in national park management zones (ZTr, Zri, Zp).

Complex stock and flow variable data is used to build a model in this research. The conceptual model by creating a CLD model of the transition system from national park land to agricultural land and residential land is the basis for creating a mathematical model, namely the SFD model. Simulations in system dynamics models cannot be carried out by using only CLD. Therefore, SFD must be built after identifying stock variables, flow variables, supporting variables (auxiliaries), and constants that complement connectivity in the system. The SFD that has been formed is then logically formulated into mathematical relationships between variables using data and parameters that can be generated from the availability of primary data (actual data), taken from the results of previous research or from other statistical report data. Stock variable data in this study includes TNBTS land area, agricultural land area, residential area, and population. The SFD model in this research analyzes the transition of national park land into agricultural land and also the transition into residential land. Meanwhile, other variable data that becomes data flow include data on bird diversity rate, lake ecosystem disruptions (lake shallowing), land use change, encroachment and then diversity index parameters such as H, E, R are called constants (Figure 5).

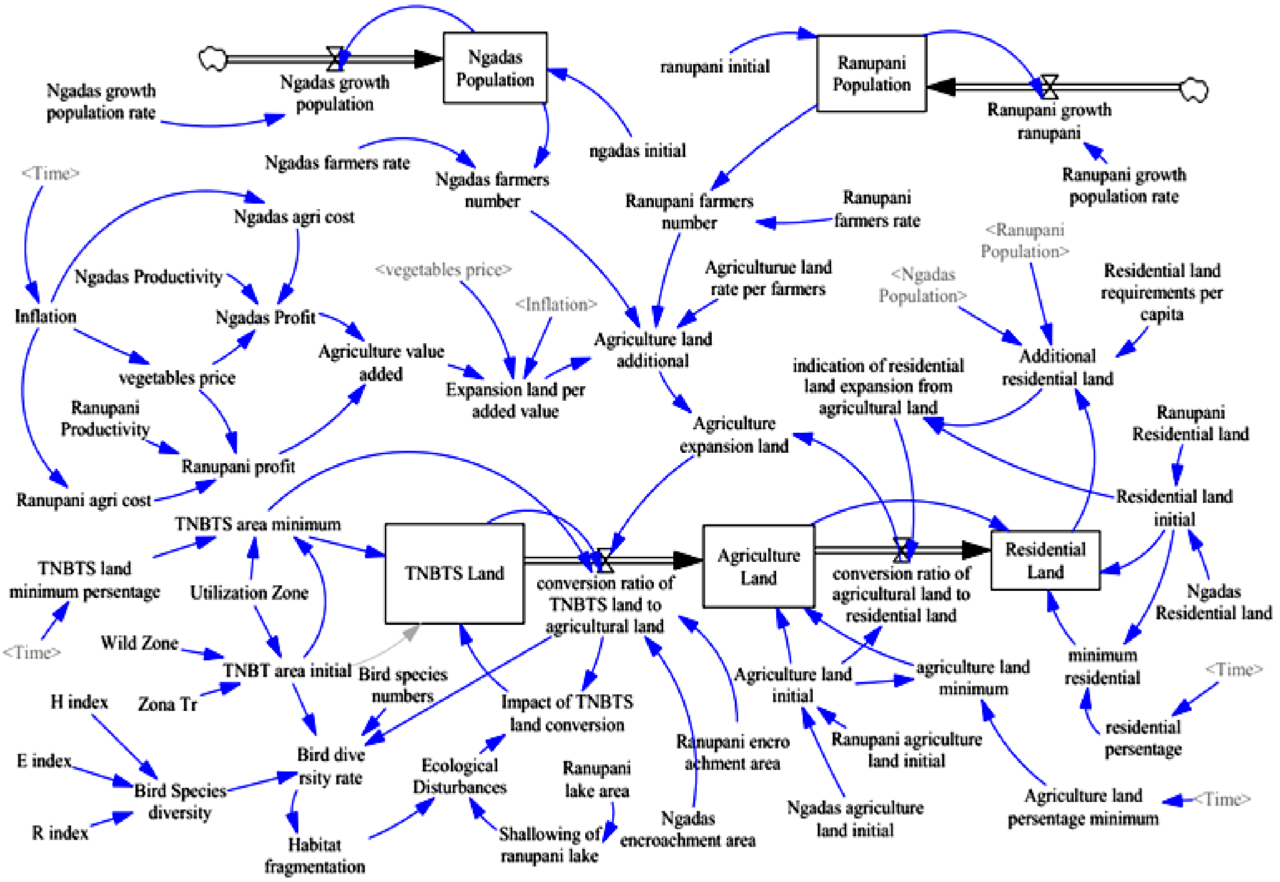


**Figure 5.** Stock Flow Diagram Model of land use changes in Bromo Tengger Semeru National Parks (TNBTS), East Java, Indonesia

The SFD model for transitioning national park land into agricultural land and residential land can be seen as follows. The model that has been built is then verified and validated by the program syntax error using Vensim PLE 8.2.1 software. The verified built SFD model is then simulated until prediction calculation results can be obtained from the system. The simulation results of the existing model based on initial data in this research from 2015 to the end point of 2050 are referred to as existing data. Scenario development can be carried out on existing models by changing variable data that has an influence on the model. Scenario development is the result of simulation using the Vensim PLE 8.2.1 application by making 4 assumptions to achieve the best conditions as expected.

The simulation results from three scenarios in the model show different graphical data after changing several parameters that have an effect on the model. The assumptions in the scenario are variations that become the driving factors for changes in several stock variables and flow variables (rate). The difference in results between the graphical data of the three scenarios and the existing data can be an important evaluation material in determining the best policy options to achieve the expected conditions. A comparison of the simulation model data between existing conditions and the three scenarios can be seen in Figures 6, 7, and 8. The graphical data of model simulation in this research (Figures 6 and 7) was obtained from spatial data processing which which behavior are predicted based on a period of time (behavior over time) from year 2015 to 2050. Meanwhile, Figure 8 is a is a representation of magnitude of changes in bird species diversity in the national park area from year 2015 to 2050. The graphical representation of the simulation results of the national park land model, agricultural land and bird diversity rate shows the differences between the existing model and the models from the three scenarios. The difference between the data from the three scenario models and the existing model explains the influence of several assumptions implemented in each scenario. `

The results of observing spatial data from the national park land area (2015) in the observation area (AOI) was 1,597.80 Ha. Existing model graphic data from national park land simulation results (Figure 6) shows a decrease in land area to 1,567.5 Ha in 2050, which means land changes (reduction in land cover) of 30.2 ha will occur. Changes in national park land can be caused by land clearing, land conversion by removing existing stands and vegetation. Land conversion in AOI is mostly used for agricultural land, which certainly can cause ecological disruptions to the preservation of biodiversity in the national park area. The model simulation results from the three scenarios in Figure 6 show that the change in national park land area is smaller than the existing model in 2050 where the land area will be 1,586.3 Ha (scenario 1), 1587.5 Ha (scenario 2) and 1591.7 Ha (scenario 3). Extensive data from the simulation results of the scenario 3 model in 2050 shows that land changes (reduction in land cover) are the smallest compared to other scenarios where the changes are only around 6.1 Ha. Meanwhile, spatial data from the agricultural land area of the enclave village in 2015 shows an area of 593.1 Ha. The graphical data of the existing model from the agricultural land simulation results (Figure 7) shows an increase in land area data to 603.3 Ha in 2050, which means there is a tendency to increase the need for agricultural land to 10.2 Ha in 2050.

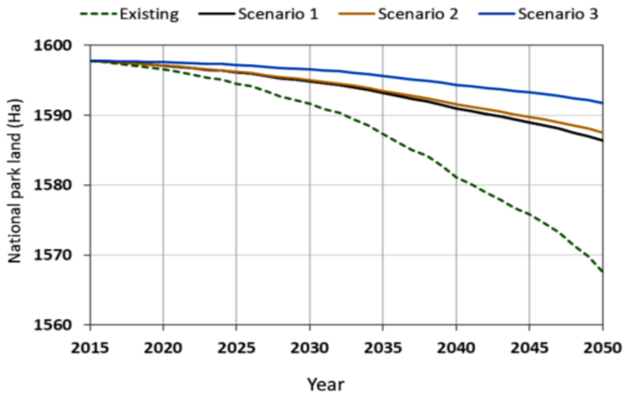


**Figure 6.** Model simulation results on existence of national park land (TNBTS, Indonesia) with scenario 1, scenario 2, and scenario 3

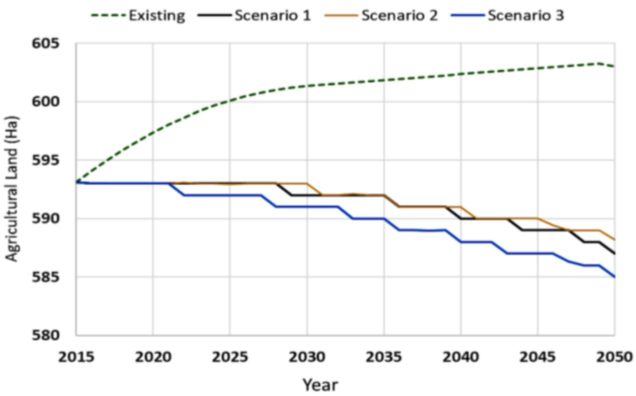


**Figure 7.** Model Simulation result of agricultural land requirements with scenario 1, scenario 2, and scenario 3

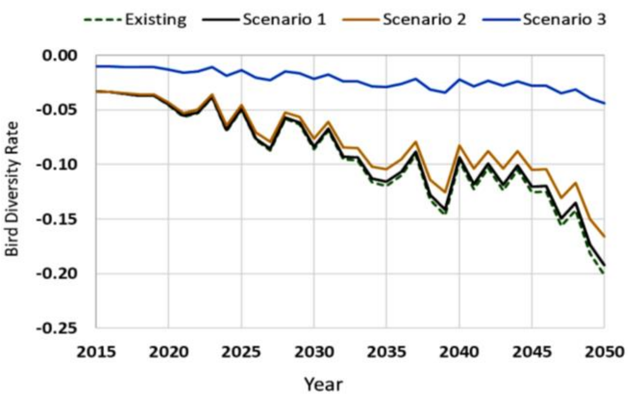


**Figure 8**. Model simulation results of the bird diversity rate with scenario 1, scenario 2 and scenario 3

In fact, the need for additional agricultural land in the enclave village is very unlikely because the land outside the enclave village is a national park area which is a conservation area and is not permitted to be converted into agricultural land. Several interventions (assumptions) in the scenario 1, scenario 2 and scenario 3 models in Figure 7 show a graphic decrease in land area until 2050 compared to the graphic data in the existing model. Scenario 3 shows the highest graphic decline where the area of agricultural land in 2050 will be 585.2 Ha or a decrease of 7.2 Ha. Furthermore, graphic data on bird diversity rate is an important variable that represents the biodiversity components in the national park area protection scenario.

Bird diversity data from observations is part of the input data to obtain index of diversity, evenness and species richness. The number of all bird species found (199 species) and recorded in the TNBTS area (Prasetya and Siswoyo 2018) is also data included in the stock flow diagram. The bird diversity rate model simulation graphic data (Figure 8) shows a graph that tends to decline in the existing model as well as in the three scenario models. The difference in values from the model simulation graph from 2015 to 2050 shows data with slight difference from the existing model (-0.17), scenario 1 (-0.16), and scenario 2 (-0.13). The graphic data from scenario 3 has a value difference (2015-2050) of -0.03 and is higher than the value difference from scenario model 1, scenario model 2, and the existing model.

The graphic from the simulation results of the national park model, agricultural land model and the bird diversity rate in Figures 6, 7, and 8 shows the differences between the existing model and the model from the three scenarios. The difference between the model data for the three scenarios and the existing model explains the existence of several influences (interventions) applied to each scenario. The existence of protected national park land, the condition of agricultural land, and the bird diversity are important variables as evaluation materials for efforts to protect national park areas and the conservation of their biodiversity. Comparing the average data from the existing model with the average data from the three scenarios is necessary to see its effect in narrowing the gap to the expected ideal conditions (Table 4).

Simulation of developing scenarios compared to existing models (Table 4) is a comparison of the average simulation results from three variables: the existence of national park land, agricultural land requirements, and bird diversity. The average percentage difference between the existing model and the three scenarios is determined by the implementation of policies (interventions) in each scenario. The simulation results of developing scenarios for the existence of national park land compared with existing model data show that the largest percentage difference is seen in scenario 3. The percentage difference in scenario 3 (0.54%) in the national park land model simulation is the greatest percentage compared to the other scenarios. This means that the interventions carried out in scenario 3 can have a positive impact on efforts to maintain the national park areas.

Furthermore, the simulation results for developing scenarios for agricultural land needs compared with the existing model data show that the largest percentage difference is in the scenario 3 (1.8%). The percentage difference between scenario 3 in the agricultural land model simulation has the greatest percentage compared to the other scenarios. The interventions carried out in the three scenarios by limiting the conversion of national park land into agricultural land and limiting agricultural land for other uses are important factors in reducing the need for agricultural land which continues to increase as seen in the existing model data. Then, intervention in the form of increase in productivity and improvement of the ecosystem in scenarios 2 and 3 can be a positive driver for reducing the need for agricultural land which tends to increase.

Meanwhile, the results of the scenario development simulation on the bird diversity rate value compared with the existing model data also show that the largest percentage difference is in the scenario 3. The percentage difference in scenario 3 (76%) in the bird diversity rate model simulation shows a very large difference and the percentage value is the greatest compared to the other scenarios. The interventions of ecosystem improvement in scenario 3 are a differentiating and important factor that has the most influence on efforts to protect national park areas while maintaining their biodiversity.

**Table 4.** Comparison of Simulation Results from Existing Models, Scenario 1, Scenario 2, and Scenario 3

| Simulation results | | Existing model | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|---|---|
| National park land (TNBTS) | Average (ha) | 1,587.12 | 1,593.33 | 1593.69 | 1595.62 |
| | Difference with existing model | 0 | 6.21 | 6.57 | 8.50 |
| | Percentage difference | 0 | 0.39% | 0.41% | 0.54% |
| Agricultural land | Average (ha) | 600.57 | 591.37 | 591.61 | 589.95 |
| | Difference with existing model | 0 | 9.20 | 8.96 | 10.62 |
| | Percentage difference | 0 | 1.53% | 1.50% | 1.80% |
| Bird diversity rate | Average | -0.09 | -0.09 | -0.08 | -0.02 |
| | Difference with existing model | 0 | 0.003 | 0.012 | 0.070 |
| | Percentage difference | 0 | 3% | 13% | 76% |

**Discussion**

In the research observation areas, important bird species were found which are included in the list of endemic and protected birds. The significance in protecting bird diversity should also be accompanied by protecting their habitat. The bird watching area carried out near the enclave village is an area that is highly recommended to maintain the condition of its vegetation. Mountain forests above 1,000 m are the most important habitat for Endemic Bird Species (EBA) because most of the forests below this altitude have changed function (MacKinnon et al. 2010). Land use and land cover changes in recent years have been quite concerning, thus methods and strategies are needed from national park management to protect conservation areas and the biodiversity within them**.** Predictions from existing model simulations at Area of Interest (AOI) show a trend of declining national park land area, expansion of agricultural land and declining bird diversity. Efforts to maintain the area of national parks from changes in land use and declines in bird diversity in the future require the best scenario for national park management policy makers.

A comparison of several scenarios shows that scenario 3 is the best scenario that can be applied to achieve the goals of protecting national park areas and maintaining biodiversity. The positive impact seen in scenario 3 is caused by the improvement interventions from scenario 1 and scenario 2 by considering the ecological aspects of the national park area. The reduction in the limit for national park land conversion to agricultural land in intervention scenario 3 was used at 10%. This reduction in limitation was carried out as a further effort regarding the status of national parks, which in essence are prohibited to be converted into productive area such as agricultural land. The emergence of bureaucratic obstacles and the economic needs of the local community means that intervention needs to be carried out to a minimum by considering the possibility of mutual benefit. Scenario 3 also focuses more on improving the ecosystem of national park land where the bird diversity rate can be improved by up to 76%. The high percentage difference between the bird diversity rate in scenario 3 (Table 4) and existing conditions is influenced by interventions to increase agricultural production by up to 30% and efforts to improve the ecosystem by up to 30%.

Ecosystem improvements can be carried out through reforestation and technical soil conservation measures in agricultural areas that have the potential for erosion. Landslides from erosion can cause the lake to receive sediment from surface flows up to the present and have an impact on the shallowing of Ranu Pani Lake. Reforestation actions can be carried out by planting local and endemic TNBTS tree species which can function as barriers to landslides and soil erosion. The ideal condition for animal habitat is to reduce edge effects and enlarge habitat patches so that the ecological system can be maintained properly (Lamb et al. 2016). The size of habitat patches with an area equivalent to creating corridors can reduce the edge effect by increasing the area of land cover (Rushdi and Hassan 2015).

A good ecological network is formed by extensive and interconnected land cover. It is anticipated that these conditions will maintain habitat and high diversity for bird species in the TNBTS conservation area. Therefore, collective efforts by related parties are required to prevent land conversion, create environmentally friendly of agricultural activities, and ensure management commitments. Several policy options are important factors to achieve the goal of protecting national park areas and their biodiversity in accordance with the best expected conditions. The process and impact of policy choices taken from dynamic systems is an important guide for constructing a model by varying driving variables, so that policy makers can determine the right choice according to the best conditions expected (Purnomo and Mendosa 2011; Aswandi et al. 2015). Achieving the best conditions requires a national park area protection strategy by policy makers related to land status, as presented in Table 5.

**Table 5.** Strategy for conservation of national park areas and enclave villages in the area of interest (AOI)

| Expected condition | Location | Area (ha) | Policy makers | Allocation and strategy |
|---|---|---|---|---|
| Preventing conversion of | ZTr, ZRi, ZP | 1,597.8 | KLHK (TNBTS) | Law enforcement: legal action against attempts to change land use and encroachment in national park areas |
| national park land | ZTr, ZRi, ZP | 1,597.8 | Lumajang District; Malang District | Socialization: appeal to village residents to comply with applicable regulations in conservation areas (national parks). |
| Preventing expansion of agricultural land in | ZTr, ZRi | 1,442.3 | KLHK (TNBTS) | Cooperation: Collaboration between TNBTS, stakeholders, and the village communities to improve the economic welfare of the village. |
| the TNBTS area | Enclave villages | 638.5 | Lumajang District; Malang District | Incentive: Regional government support for efforts to increase agricultural productivity and business diversification on enclave village lands |
| Improving ecosystem and | ZTr, Zri, ZP | 1,597.8 | KLHK (TNBTS) | Protection: land rehabilitation, reforestation, and protection of endemic animal and flora habitats |
| conserving biodiversity | Enclave villages | 638.5 | Lumajang District; Malang District | Adaptive: Support and encouragement by local governments for village communities to participate in protecting national park areas and their biodiversity |

Note: ZTr: Traditional Zone (1,402.3 Ha); ZRi: Wilderness Zone (40.0 Ha); ZP: Utilization Zone (155.5 Ha); Enclave Villages (Ngadas: 373.2 Ha, Ranupani: 265.3 Ha) KLHK: Indonesian Ministry of Environment and Forestry; TNBTS: Bromo Tengger Semeru National Park, Indonesia; Lumajang District: Local Government of Lumajang District, East Java, Indonesia; Malang District: Local Government of Malang District, East Java, Indonesia

The results of this research initiated several policy inputs to achieve the goal of obtaining the best desired conditions through several strategies. The model development is expected to be applied in determining management decisions, understanding the process and impact of the policy choices that will be established. The description of data from model simulations and several alternative scenarios can also be used as a means and tool for policy makers to optimize the protection of conservation areas (national parks) and their biodiversity. It is expected that the application of the simulation model from this research can also be applied to similar conditions and problems, particularly with further validation of several parameters and variables that will be used.

## ACKNOWLEDGEMENTS

We would like to express our gratitude to all parties who supported this research, especially to Bromo Tengger Semeru National Park (TNBTS), East Java, Indonesia namely Koestriadi Nugra Prasetya, Agung Siswoyo, everyone involved in the field, Miss Mifta as a sysdyn data processor and Mr. M. Ardiansyah as a spatial data processor. In addition, we would like to express our gratitude to Universitas Brawijaya, Malang, Indonesia as well as support to the President Director of PT. Bromo Permai Probolinggo, Indonesia.

## REFERENCES

Andonegi A, Garmendia E, Aldezabal A. 2021. Social multi-criteria evaluation for managing biodiversity conservation conflicts. Land Use Pol 109: 1-14. DOI: 10.1016/j.landusepol.2021.105658.

Aswandi, Ronggo S, Supriyo H, Hartono. 2015. Tropical peat swamp management options: A case study using system dynamic in Southern Aceh. Jurnal Manajemen Hutan Tropika 21 (3): 172-183. DOI: 10.7226/jtfm.21.3.172.

Balai Besar Taman Nasional Bromo Tengger Semeru (BBTNBTS). 2015. Information Book Bromo Tengger Semeru National Park. Balai Besar Taman Nasional Bromo Tengger Semeru, Malang. [Indonesian]

Banson KE, Asare DK, Dery FD, Boakye K, Boniface1A, Asamoah M, Awotwe LE. 2020. Impact of fall armyworm on farmer's maize: Systemic approach. Syst Pract Action Res 33 (2): 237-264. DOI: 10.1007/s11213-019-09489-6.

Barbrook JP, Penn AS. 2022. System dynamics. Syst Mapping: 13-128. DOI: 10.1007/978-3-031-01919-7_8.

Bhusal N, Sneha P. 2021. Avian diversity and abundance in the Machhaplan Complex, Hetauda, Nepal. For J Institute For Nepal 18 (01): 90-106. DOI: 10.3126/forestry.v18i01.41762.

Bibby CJ, Burgess ND, Hill DA, Mustoe S. 2000. Bird Census Techniques, Second Edition. Academic Press, United Kingdom.

BirdLife International. 2004. Important Birds Areas in Asia: Key Sites for Conservation. Birdlife International, Cambridge.

BirdLife International. 2023. Endemic Bird Areas Factsheet: Java and Bali Forest. http://datazone.birdlife.org/eba/factsheet/160 on 25/09/2023.

Blicharska M, Angelstam P, Giessen L et al. 2020. Between biodiversity conservation and sustainable forest management-A multidisciplinary assessment of the emblematic Białowieza Forest case. Biol Conserv 248: 1-15. DOI: 10.1016/j.biocon.2020.108614 .

Boyce C, Neale P. 2006. Conducting In-Depth Interview: A Guide for Designing and Conducting In-depth Interviews for Evaluation Input. Pathfinder International Tool Series, Monitoring and Evaluation-2. http://www.pathfind.org/site/DocServer/m_e_tool_series_indepth_interviews.pdf?docID=6301

Daly AJ, Baetens JM, De Baets B. 2018. Ecological diversity: Measuring the unmeasurable. Mathematics 6 (7): 1-28. DOI: 10.3390/math6070119.

Degele PE. 2023. Protected areas in land use planning policies: Key articulation for territorial justice. Environ Sci Pol 140: 189-201. DOI: 10.1016/j.envsci.2022.11.020.

Dietz J, Treydte AC, Lippe M. 2023. Exploring the future of Kafue National Park, Zambia: Scenario-based land use and land cover modelling to understand drivers and impacts of deforestation. Land Use Poli 126: 1-18. DOI: 10.1016/j.landusepol.2023.106535.

Eaton JA, Van Balen B, Brickle NW, Rheindt FE. 2016. Birds of The Indonesian Archipelago. Greater Sundas and Wallacea. Lynx Edicions, Barcelona.

Ezquerro M, Balteiro LD, Pardos M. 2023. Implications of forest management on the conservation of protected areas: A new proposal in Central Spain. For Ecol Manag 548: 1-14. DOI: 10.1016/j.foreco.2023.121428.

Holland A, Gibbons, P, Thompson J, Roudavski S. 2023. Modelling and design of habitat features: Will manufactured poles replace living trees as perch sites for birds? Sustainability 15 (9): 1-30. DOI: 10.3390/su15097588.

Horigue V, Richards R, Taju A, Maina J. 2023. Disentangling the influence of the economic development discourse on the management of national parks through systems thinking: Case studies from the Philippines and Mozambique. Land Use Pol 125: 1-14. DOI: 10.1016/j.landusepol.2022.106499. https://jdih.menlhk.go.id/new2/home/portfolioDetails/76/2015/4 on 23/06/ 2023. [Indonesian]

Huang CW, McDonald RI, Seto KC. 2018. The importance of land governance for biodiversity conservation in an era of global urban expansion. Landsc Urban Plan 173: 44-50. DOI: 10.1016/j.landurbplan.2018.01.011.

Ioki K, Din NM, Ludwig R, James D, Hue SW, Johari SA, Awang RA, Anthony R, Phua MH. 2019. Supporting forest conservation through community-based land use planning and participatory GIS - lessons from Crocker Range Park, Malaysian Borneo. J Nat Conserv 52: 1-11. DOI: 10.1016/j.jnc.2019.125740.

Kaban A, Mardiastuti A, Mulyani YA. 2017. Response of bird community to various plantation forests in Gunung Walat, West Java, Indonesia. Hayati J Biosci 24 (2):72-78. DOI: 10.1016/j.hjb.2017.08.006.

Karami S, Karami E, Buys L, Drogemuller R. 2017. System dynamic simulation: A new method in Social Impact Assessment (SIA). Environ Impact Asses Rev 62: 25-34. DOI: 10.1016/j.eiar.2016.07.009.

Kavwele CM., Torney CJ, Morrison TA, Fulford S, Masolele MM, Masoy J, Hopcraft JGC. 2022. Non-local effects of human activity on the spatial distribution of migratory wildlife in Serengeti National Park, Tanzania. Ecol Solut Evid 3: 1-12. DOI: 10.1002/2688-8319.12159.

Krebs CJ. 1985. Experimental Analysis of Distribution and Abundance, Third Edition. Harper & Row Publisher, New York.

Lamb A, Balmford A, Green RE, Phalan B. 2016. To what extent could edge effects and habitat fragmentation diminish the potential benefits of land sparing? Biol Conserv 195: 264-271. DOI: 10.1016/j.biocon.2016.01.006.

Lane DC. 2000. Diagramming conventions in system dynamics. J Oper Res Soc 51 (2): 241-245. DOI: 10.2307/254265.

Levers C, Romero MA, Baumann M, De Marzo T, Fernández PD, Gasparri NI, Gavier PGI, Waroux YLP, Piquer RM, Semper PA, Kuemmerle T. 2021. Agricultural expansion and the ecological marginalization of forest-dependent people. Proceed Natl Acad Sci 118 (44): 1-9. DOI: 10.1073/pnas.2100436118.

Ludwig JA, Reynolds JF. 1988. Statiscal Ecology-A Primer and Methods and Computing. Wiley, New York.

Ma S, Wang LJ, Jiang J, Zhao YG. 2023. Direct and indirect effects of agricultural expansion and landscape fragmentation processes on natural habitats. Agric Ecosyst Environ 353: 1-15. DOI: 10.1016/j.agee.2023.108555.

MacKinnon J, Phillipps K, Van Balen B. 2010. Seri Panduan Lapangan Burung-Burung di Sumatera, Jawa, Bali dan Kalimantan. Bogor: Birdlife International-Indonesia Program-Pusat Penelitian dan Pengembangan Biologi. LIPI, Bogor. [Indonesian]

Magurran AE. 2004. Measuring Biological Diversity. Blackwell, Oxford.

McCarthy C, Banfill J, Hoshino B. 2021. National parks, protected areas and biodiversity conservation in North Korea: Opportunities for international collaboration. J Asia-Pac Biodivers 14 (3): 290-298. DOI: 10.1016/j.japb.2021.05.006.

Minister of Environment and Forestry. 2015. The Minister of Environment and Forestry of Republic of Indonesia Regulation Number: P.76/Menlhk-Setjen/2015 Criteria for management zones of National Park and management blocks of Nature Reserve, Wildlife Reserve, Grant Forest Park, and Natural Tourism Park.

Monat JP, Gannon TF. 2023. The Meaning of structure in systems thinking. Systems 11 (92): 1-17. DOI: 10.3390/systems11020092.

Naugle A, Langarudi S, Clancy, T. 2024. What is (quantitative) system dynamics modeling? Defining characteristics and the opportunities they create. Syst Dyn Rev 40 (2): 1-14. DOI: 10.1002/sdr.1762.

Novriyanti, Ihsan I, Irawan B, Wulan C. 2021. Fragmented urban areas: Can plants encourage birds in Jambi City urban space? IOP Conf Ser: Earth Environ Sci 918 (012028): 1-12. DOI: 10.1088/1755-1315/918/1/012028.

Pires MM, Benchimol M, Cruz LR, Peres CA. 2023. Terrestrial food web complexity in Amazonian forests decays with habitat loss. Curr Biol 33: 389-396. DOI: 10.1016/j.cub.2022.11.066.

Poudel B, Neupane B, Joshi R, Silwal T, Raut N, Thanet, DR. 2021. Factors affecting the species richness and composition of bird species in a community managed forest of Nepal. J Threat Taxa 13 (9): 19212-19222. DOI: 10.11609/jott.6945.13.9.19212-19222.

Prasetya KN, Rahmadana M, Siswoyo A, Widodo R, Winedar DW. 2018. Burung-burung di Taman Nasional Bromo Tengger Semeru. Balai Besar Taman Nasional Bromo Tengger Semeru, Malang. [Indonesian]

Prasetya KN, Siswoyo A. 2018. Keanekaragaman Burung-Burung di Taman Nasional Bromo Tengger Semeru. Prosiding KPPBI 4. LPPM Universitas Negeri Semarang, Semarang. [Indonesian]

Purnomo H, Mendoza G. 2011. A system dynamics model for evaluating collaborative forest management: A case study in Indonesia. Intl Sustain Dev World Ecol 18 (2): 164-176. DOI: 10.1080/13504509.2010.549664.

Qiu Y, Shi X, Shi C. 2015. A system dynamics model for simulating the logistics demand dynamics of metropolitans: A case study of Beijing, China. J Indust Eng Manag 8 (3): 783-803. DOI: 10.3926/jiem.1325.

Rushdi AMA, Hassan AK. 2015. Reliability of migration between habitat patches with heterogeneous ecological corridors. Ecol Model 304: 1-10. DOI: 10.1016/j.ecolmodel.2015.02.014.

Schoenenberger L, Schmid A, Tanase R, Beck M, Schwaninger M. 2021. Structural analysis of system dynamics models. Simul Model Pract Theory 110: 1-20. DOI: 10.1016/j.simpat.2021.102333.

Shin N, Bowers J, Roderick, S, McIntyre C, Stephens AL, Eidin E, Krajcik J, Damelin D. 2022. A framework for supporting systems thinking and computational thinking through constructing models. Instr Sci 50 (6): 933-960. DOI: 10.1007/s11251-022-09590-9.

Sterman J D. 2002. System Dynamics: Systems Thinking and Modeling for a Complex World. Massachusetts Institute of Technology Engineering Systems Division. MIT Sloan School of Management. http://hdl.handle.net/1721.1/102741.

Stockwell S, Claire G, Dunlop JN, Loneragan NR. 2021. Distribution and foraging by non-breeding Caspian Terns on a large temperate estuary of south-western Australia-preliminary investigations. Pac Conserv Biol 28: 48-56. DOI: 10.1071/PC20082.

Tongco MDC. 2007. Purposive sampling as a tool for informant selection. Ethnobot Res Appl 5: 147-158. DOI: 10.17348/era.5.0.147-158.

Wei D, Feng A, Huang J. 2020. Analysis of ecological protection effect based on functional zoning and spatial management and control. Intl J Geoheritage Parks 8 (3): 166-172. DOI: 10.1016/j.ijgeop.2020.06.003.

Xinjian W, Chen J, Zhou L. 2020. Effects of human activities on the diversity of waterbirds wintering in a Shallow Lake of the middle and lower Yangtze River Floodplain, China. Diversity 12 (8): 1-14. DOI: 10.3390/d12080302.

Zakkak S, Kakalis E, Radović A, Halley J, Kati V. 2013. The impact of forest encroachment after agricultural land abandonment on passerine bird communities: The case of Greece. J Nat Conserv 22 (2): 157-165. DOI: 10.1016/j.jnc.2013.11.001.