Table S4: The general equation used in the construction of the KVT version 1.0 model.

Biomass and primary production.

The producer is a state variable that provides biomass as food/energy for herbivores. Biomass is the net primary productivity (NPP), which is a function of gross primary productivity (GPP) minus the energy loss due to metabolic respiration and maintenance, expressed as growth respiration (Rg) and maintenance respiration (Rm) (Eq. D.1). NPP represents the level of energy stored as biomass by plants as producers and is the energy available to primary consumers (herbivores) within the ecosystem.

$$NPP_t = GPP_t - (Rg + Rm) \qquad \text{(D.1)}$$

GPP is a function of variables and parameters derived from satellite data, such as land cover and light-use efficiency (LUE) (Eq. D.2).

$$GPP = \varepsilon_g \times FPAR_i \times PAR \qquad \text{(D.2)}$$

Where ε_g is the light-use efficiency expressed in photosynthetic photon flux density (µmol $m^{-2}s^{-1}$), FPAR is the fraction of photosynthetically active radiation, and PAR is the solar radiation within the electromagnetic wavelength range for photosynthesis (photosynthetic active radiation) derived from the global radiation value Qn. In this study, ε_g is defined as a value influenced by the mean state of ecosystem temperature sensitivity changes (dTe), water content (W), and leaf area index (LAI), as well as maximum light-use efficiency (ε_0) (Eq. D.3). According to the temporal resolution of the model (annual), the values of T, W, and LAI are annual averages (t).

$$\varepsilon_g = \varepsilon_0 \times dTe_t \times W_t \times ILD_t \qquad \text{(D.3)}$$

The value of ε_0 in this study uses reference values from previous studies. dTe which indicates the sensitivity of photosynthesis to temperature conditions, is derived from the model developed by Raich et al. (1991) for terrestrial ecosystems and is a function of average air temperature (T_{ave}), maximum air temperature (T_{max}), minimum air temperature (T_{min}), and optimum monthly photosynthesis temperature (T_{opt}). T_{opt} uses values developed by Vetrita et al. (2011), which is 28°C. The value of W is the result of the land water balance submodel, and LAI is a function of land cover (Lcov).

The values of R_g and R_m are functions of biomass (W_{t-1}) and air temperature (T). This study uses a single respiration value, which is the sum of these two respirations (Rt). The rate of respiration will increase with increasing T values (Eq. D.4 and D.5).

$$Q_{10} = 2^{\frac{(T-20)}{10}} \qquad \text{(D.4)}$$

$$Rt = km \times W_{t-1} \times Q_{10} \qquad \text{(D.5)}$$

The model uses a simplified trophic level approach to determine the role of each mammalian species. Each trophic level has different energy allocation. As the initial value for the model, the proportion of energy allocation (kcal/m²/year) at each trophic level uses the conservation and energy balance approach (Odum, 1994) (Figure D.1). This model shows the balance of GPP with the accumulation of respiration energy (R) and decay (D). In the model with annual temporal resolution, this balanced condition indicates that there is no energy reserve (ΔS) for year n+1 (Eq. D.6). Therefore, empirical data on the presence of mammalian species and NPP are used to generate the energy reserve variable for year n, ensuring continuous energy availability until year n+1. The initial value of ΔS is derived from biomass values based on land cover in year n.

$$GPP_n = R_n + D_n + \Delta S_{n-1}, \quad \Delta S = 0 \qquad \text{(D.6)}$$

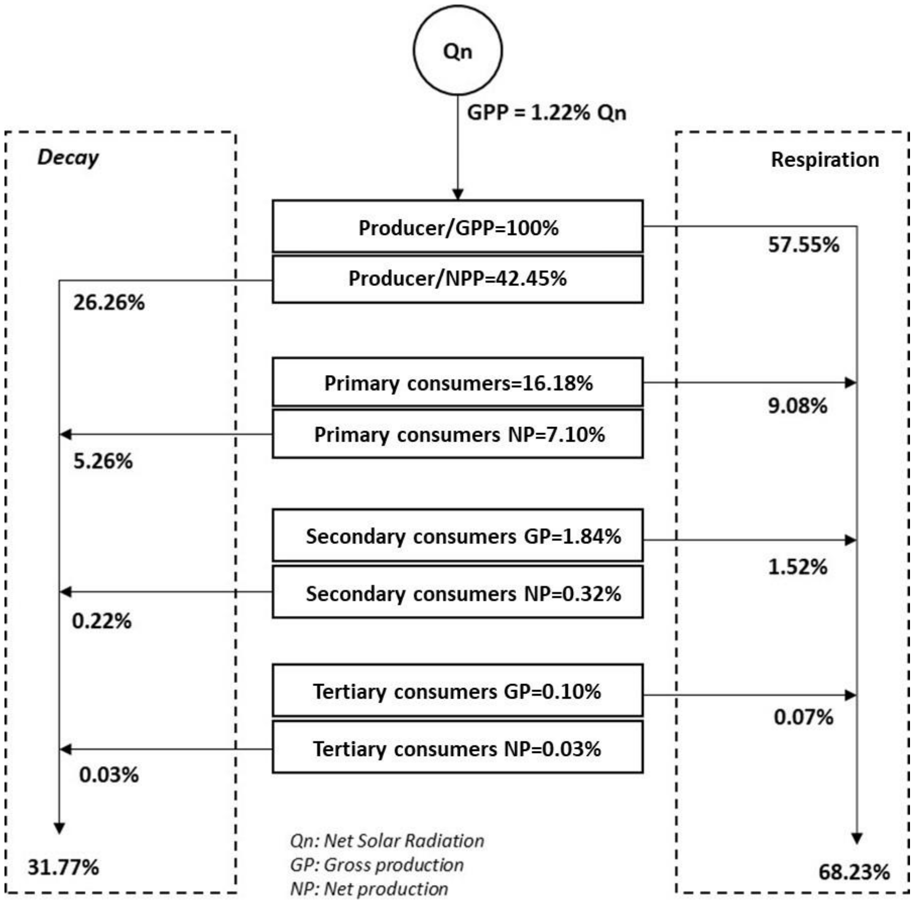

Figure D.1. Initial value scheme of the model for energy allocation and proportion at each trophic level (modified from Odum 1994).

Species presence and abundance

The presence of each species is inferred from the potential utilization of NPP (Ue) by each primary consumer (Hi). The initial value of species abundance (∑Hi) is obtained from an analysis of their distribution maps and habitat preferences, which have been validated with survey data and relevant references. Habitat preferences are simplified using land cover variables. The determination of species abundance for secondary and tertiary consumers is based on the fundamental Lotka-Volterra equations, which describe the interactions between predators and prey (Eq. D.7 and D.8). This model is often used to explain predator-prey interactions, competition, disease, and mutualism.

$$\frac{dX}{dt} = \alpha X - \beta XY, \tag{D.7}$$

$$\frac{dY}{dt} = \delta XY - \gamma Y \tag{D.8}$$

Where X represents the prey species population, Y represents the predator species population, dx/dt and dy/dt are the population growth rates of the species, and t is time. Parameters α, β, δ, and γ represent environmental factors such as climate, land cover, and food availability, as well as species-specific characteristics such as basal metabolic rate, normal body weight, dietary diversity, individual/group behavior, habitat or nesting preferences, offspring number, sexual maturity age, and biological age.

In this study, the prey and predator species are not singular but rather a set consisting of several species, i.e., {X1, X2, X3.....Xn} and {Y1, Y2, Y3.....Yn}. Each species is interconnected with different environmental parameters. The model translocates a portion of the NPP value to the initial consumers (herbivores), where each species has a different Ue value. This is used to determine the parameters of each species interaction (Eq. D.9).

$$\beta NPP = \sum_{i=1}^{n} Ue_i X_i \tag{D.9}$$

Where βNPP is the amount of ecosystem primary production consumed by herbivores, Ue_i is the efficiency of food utilization by herbivore species X_i (H_i). The number of individuals of each species X_i is determined based on weighted optimization using back propagation with the target fulfillment of βNPP, allowing the weights of each species to determine the number of individuals X_i within a specific area, considering environmental variables.

The available prey for carnivores at trophic level-n (EC) is obtained from the relationship between the population numbers of X_i, the assimilation efficiency of each prey species (Ae), and the food utilization efficiency by carnivore specie Y_i (C_i). The presence and number of individuals of carnivore species at a specific area are the results of weighting the EC values.

One of the constraints in this study is the lack of continuous observations over time regarding the presence and population of species at surveyed locations. To overcome this constraint, U_e values, EC weighting, and parametric solutions are used to estimate initial individual numbers at each survey location. These parametric solutions demonstrate the predator-prey relationships, represented in Cartesian diagrams with prey on the x-axis and predators on the y-axis, eliminating the time function (dt). Substituting dt in equations 7 and 8 results in the equilibrium relationship between predator and prey as follows (Eq. D.10, D.11, and D.12).

$$\frac{dy}{dx} = -\frac{y}{x}\frac{\delta x-\gamma}{\beta y-\alpha} \tag{D.10}$$

$$\frac{\beta y-\alpha}{y}\,dy + \frac{\delta x-\gamma}{x}\,dx = 0 \tag{D.11}$$

$$V = \delta x - \gamma \ln(x) + \beta y - \alpha \ln(y) \tag{D.12}$$

Where V is a constant initial condition depending on parameters α, β, δ, and γ. These parameters are determined based on empirical values from previous research studies.