Spatiotemporal Variations of Albedo in Managed Agricultural Landscapes: Inferences to Global Warming Impacts (GWI)

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Challenges: What is not known?

- Land use and the consequent land mosaics directly determine landscape processes and functions, such as the magnitude and dynamics of ecosystem-to-landscape **Albedo** – an **unexplored** pattern-processes in landscape ecology.
- Based on changes in albedo (**Δα**), the cooling and/or warming effects due to land mosaics have been sporadically reported as albedo-induced global warming impact (**$GWI_{\Delta\alpha}$**).
- Spatial and temporal variations in **$GWI_{\Delta\alpha}$** of managed agricultural landscapes are **unknown**.

Objective

To investigate the spatial and temporal changes of **cumulative $GWI_{\Delta\alpha}$** by connecting it with the structure of an intensively managed landscape in the Kalamazoo watershed in southwestern Michigan.

$$[\Delta\alpha_i \times \Delta \boldsymbol{area}_l \times \Delta \boldsymbol{climate}_l] \rightarrow \boldsymbol{cumulative}\ \Delta \boldsymbol{GWI}_{\Delta\alpha} \qquad (1)$$

Data

- **Landscape structure:** The Landsat-derived land cover map of 2011 was obtained performing the supervised classification, following the Andersons level I classification scheme : 1) Urban, 2) Croplands, 3) Barrens, 4) Forests, 5) Water, 6) Wetlands, and 7) Grasslands.
- **Albedo**: White-sky albedo shortwave radiations in 2012, 2016 and 2017 were processed based on the MODIS Bidirectional Reflectance Distribution Function (BRDF) MCD43A3 (V006) product.
- **Precipitation:** Daily precipitation was generated from the Parameter-elevation Regressions on Independent Slopes Model group (PRISM) AN81d product for 2012-2016-2017. The annual precipitation was used to classify each year into "wet", "dry" or "normal".

Methods

- **Estimating albedo-induced radiative forcing ($RF_{\Delta\alpha}$) and $GWI_{\Delta\alpha}$:** To quantify the cooling/warming effects on the climate, we calculated the direct RF of Δα at the top-of-atmosphere (**$RF_{\Delta\alpha}$**) using Eq. 2:

$$RF_{\Delta\alpha}(t) = -\frac{1}{n} \times \sum_{d=1}^{n} SW_{in} \times T_a \times \Delta_\alpha \qquad [W \cdot m^{-2}] \qquad (2)$$

where *n* is the number of the days of the entire growing season, SW_{in} is the incoming solar radiation at the surface, T_a and $\Delta\alpha$ are the upward atmospheric transmittance and the difference of cropland and forest (i.e., the reference cover type of the landscape) albedos, respectively. All the variables refer to a specific time of 10:30 am (e.g., MODIS terra morning overpass time).

To quantify the mitigation of CO_2-equivalent due to Δα, we calculated **$GWI_{\Delta\alpha}$** using Eq. 3:

$$GWI_{\Delta\alpha} = \frac{S \times RF_{\Delta\alpha\,(t)}}{A \times AF \times rf_{CO_2}} \times \frac{1}{TH} \qquad \left[g\ CO_{2\ eq.} \cdot \mathrm{m}^{-2} \cdot\ yr^{-1}\right] \qquad (3)$$

S and *A* are the area of the cover type (to be compared with forest) and the landscape, respectively, *TH* is the time horizon (100 yrs) of the potential global warming, *AF* is the decay rates of a 1-kg CO_2 (52%), and rf_{CO2} is a constant (0.908 W · kg CO_2^{-1}).

What is the contribution of managed patches to landscape $GWI_{\Delta\alpha}$?

Connecting landscape-structure/use to global warming – the Cooling Effects

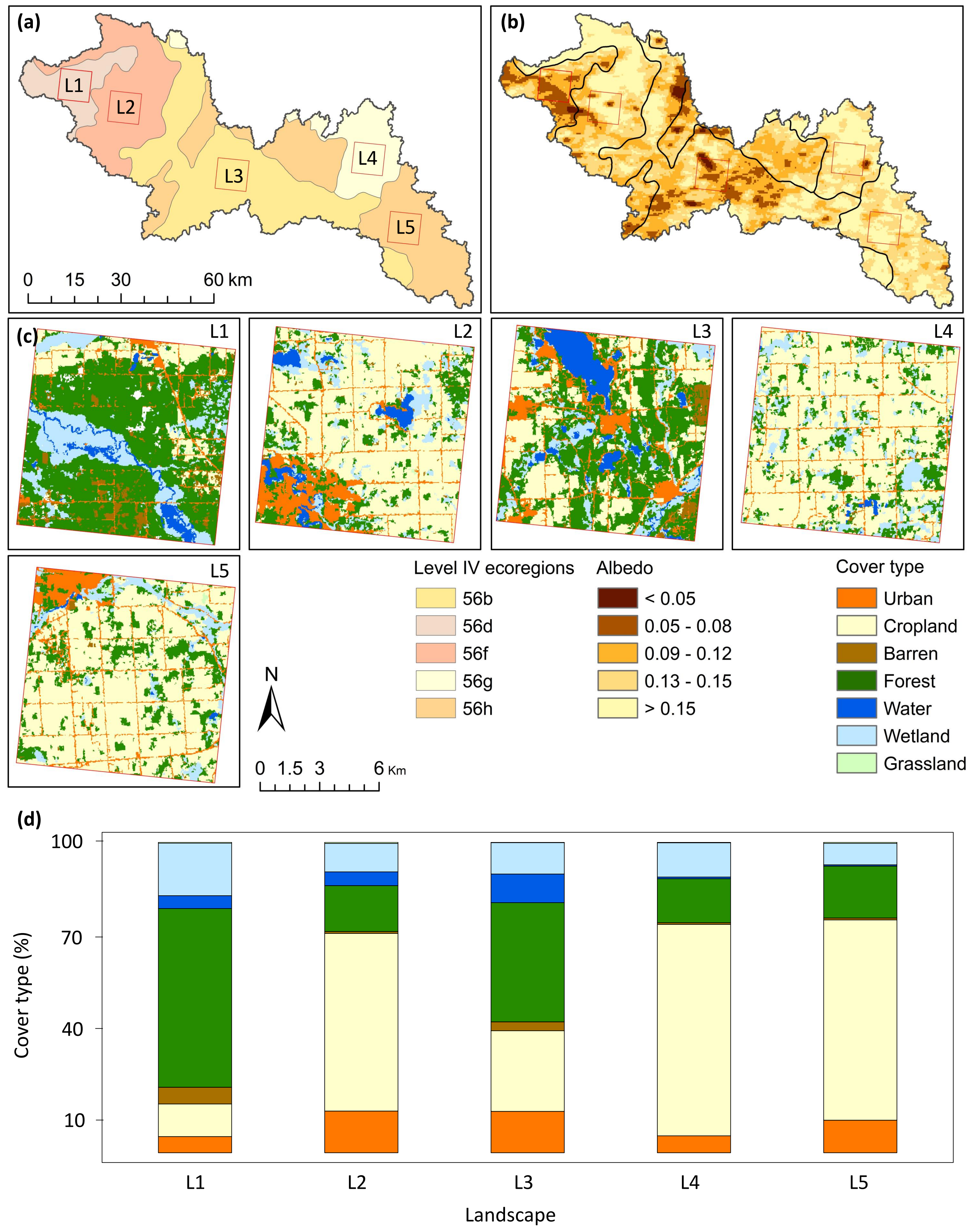
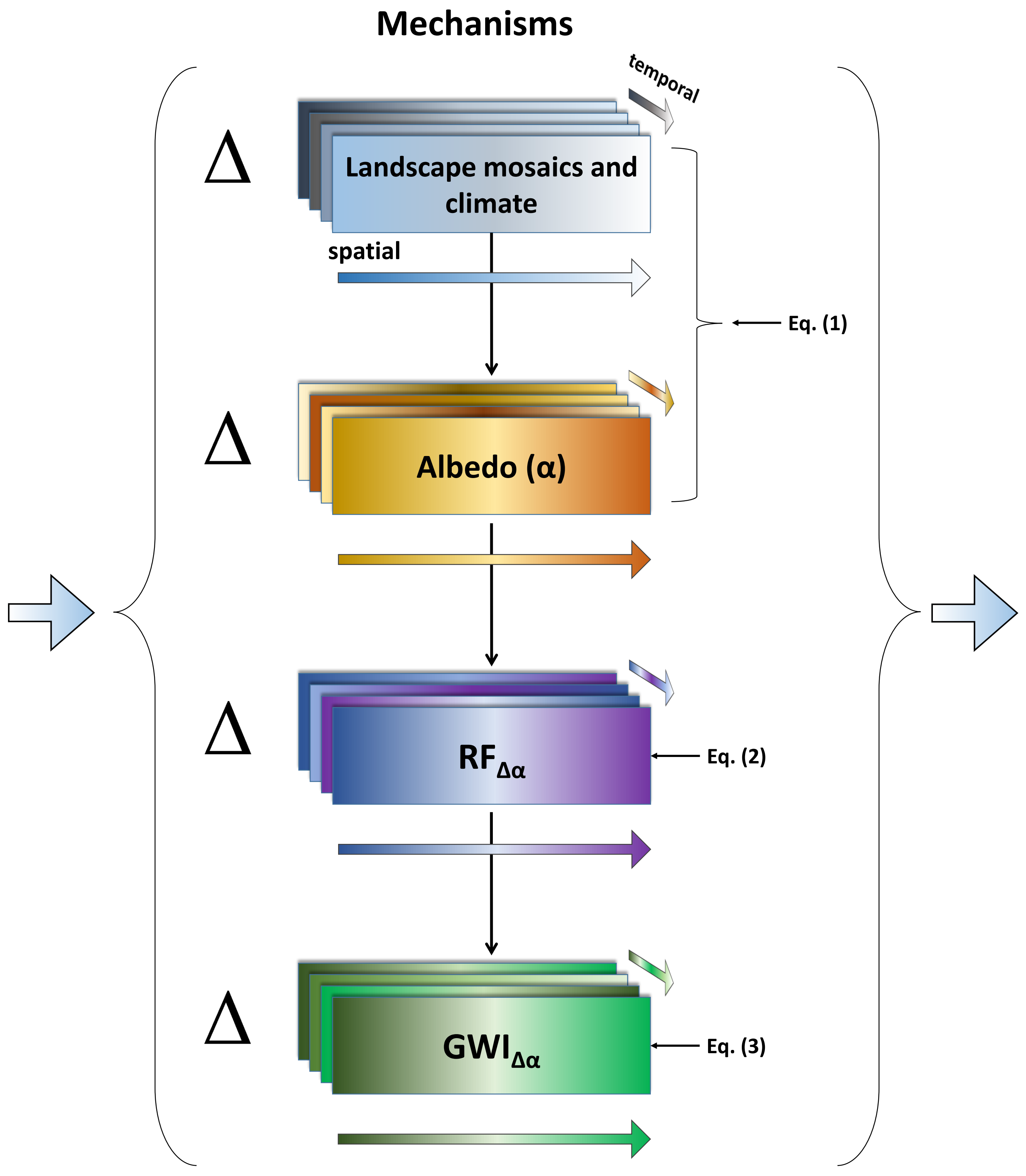
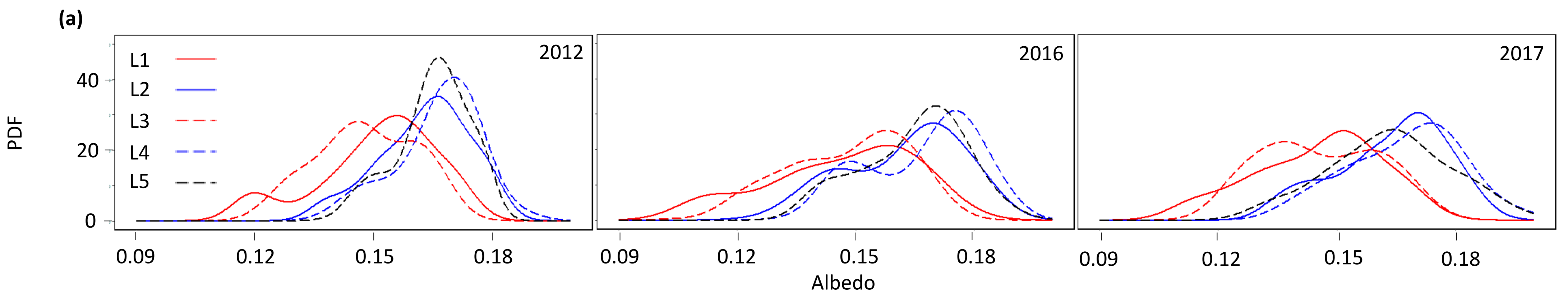


Figure 1. (a) Location of the five landscapes (L1-L5) and ecoregion types (56b to 56h) within the Kalamazoo watershed; (b) spatial changes in annual mean albedo in 2012; (c) landscape structure of L1-L5; and (d) composition (%) of the five landscapes**.**





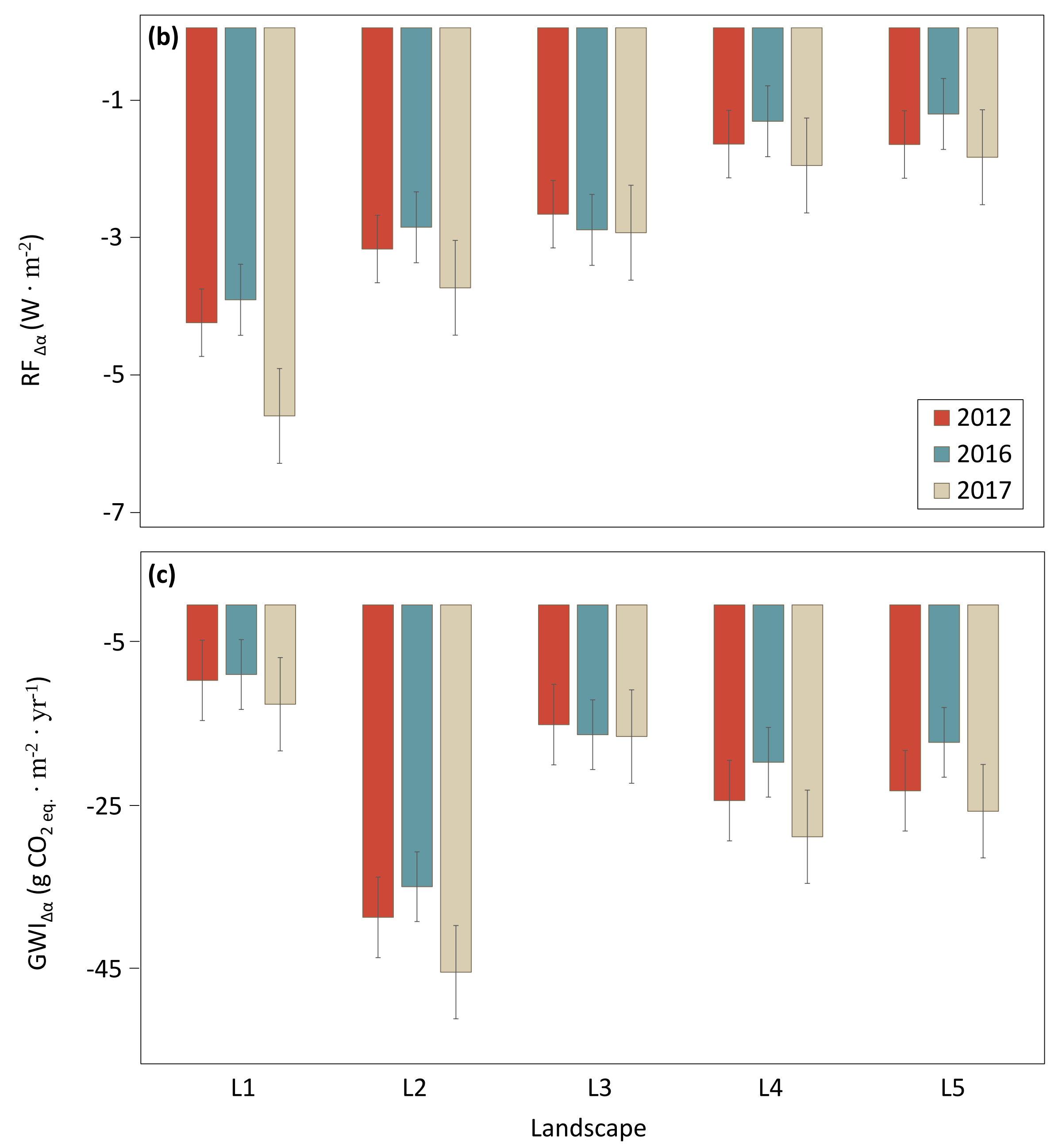


Figure 3. (a) Probability density function (PDF) of *albedo* for the five landscapes in 2012, 2016 and 2017. (b) Radiative forcing; and (d) global warming impact (c) due to difference in albedo (Δα) between cropland and forest in dry (2012), wet (2016), and normal (2017) years. Negative values indicate a global warming mitigation impact – **the cooling effects**.

Findings

- Two of the five landscapes (L1 and L3) are **dominated by forests**, with a coverage (%) of 57.5 in L1 and 38.4 in L3. **Croplands dominated** other three landscapes, with a coverage (%) of 57.2, 68.1, and 64.5 in L2, L4, and L5, respectively.
- **Albedo** is **lower** in **L1** and **L3** than that in L2, L4, and L5. However, the **intra-annual Δα** is **higher** in **L1** and **L3** (~normally distributed) than that in L2, L4, and L5, (right skewed and with the lowest variation found in 2012).
- **$RF_{T\Delta\alpha}$** (W · m^{-2}) is highest (**cooling effect**) in L1 in 2017 (-5.58), lowest (**warming effect**) in L5 in 2016 (-1.24).
- **GWIΔα** (g $CO_{2\ eq.}$· m^{-2} · yr^{-1}) is lower in agriculture-dominated landscapes than that in forest-dominated ones, indicating that croplands have **higher CO_2 mitigation impact – the cooling effects**. In particular, L1 has the lowest CO_2 mitigation (~9 to 12), while L2 has the highest (~35 to 45), which is similar to the net soil C storage of annual crops, more than double the net GWI of perennial crops, and higher than the offsets of GHG costs of both faming inputs and N_2O losses of conventional/no-till systems for the study region.