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► To cite this version:

Fabrice Dubertret, François-Michel Le Tourneau, Miguel Villarreal, Laura Norman. Monitoring Annual Land Use/Land Cover Change in the Tucson Metropolitan Area with Google Earth Engine (1986-2020). International Symposium of Labex DRIIHM, Jun 2022, Nantes, France. halshs-03960570

HAL Id: halshs-03960570

<https://shs.hal.science/halshs-03960570>

Submitted on 27 Jan 2023

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Monitoring Annual Land Use/Land Cover Change in the Tucson Metropolitan Area with Google Earth Engine (1986–2020)

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CONTEXT

The city of Tucson and the upper Santa Cruz River Valley are located in the Sonoran Desert of southeastern Arizona (USA), a region affected by both **massive population growth** and **rapid climate change**. As a consequence, its **fragile arid ecosystem undergoes increasing pressure** resulting in important land use / land cover (LULC) transformations. This paper proposes a generic and innovative method to fit the crucial need of **monitoring and quantifying landscape evolution** over several decades.

MATERIAL AND METHODS

We mobilized the tremendous computing capacities of **Google Earth Engine (GEE)** to create **yearly LULC maps from 1986 to 2020**, in a 5 steps workflow:

- 1. Data pre-processing**, consisting of invalid pixels (e.g. clouds) masking, illumination (BRDF) and topographic corrections, and mosaicking of **bi-seasonal Landsat imagery** for each year;
- 2. Computation of ancillary data**, including Multitemporal Kauth-Thomas (MKT) Transformation, calculation of various indices for better detection of bare, vegetated and built areas, Gray-Level Co-occurrence Matrix (GLCM) textural features for each band and index, and other contextual geographic data such as the slope, or buffered streams and roads;
- 3. Random Forest classification**, using the resulting 124 layers of information a year as input, as well as a stratified training sample of 4874 points within 955 polygons (5,472.5 ha) representing 14 LULC classes;
- 4. Image post-processing** involved cleaning the yearly modeled LULC maps with a majority filter, filling remaining data gaps with closest available value, temporal smoothing of detected changes to focus on pluriannual trends, and automated correction of persistent misclassified urban pixels;
- 5. Accuracy assessment** with a set of 4960 stratified sample points from 968 validation polygons (5,106.7 ha) representing the same 14 LULC classes.

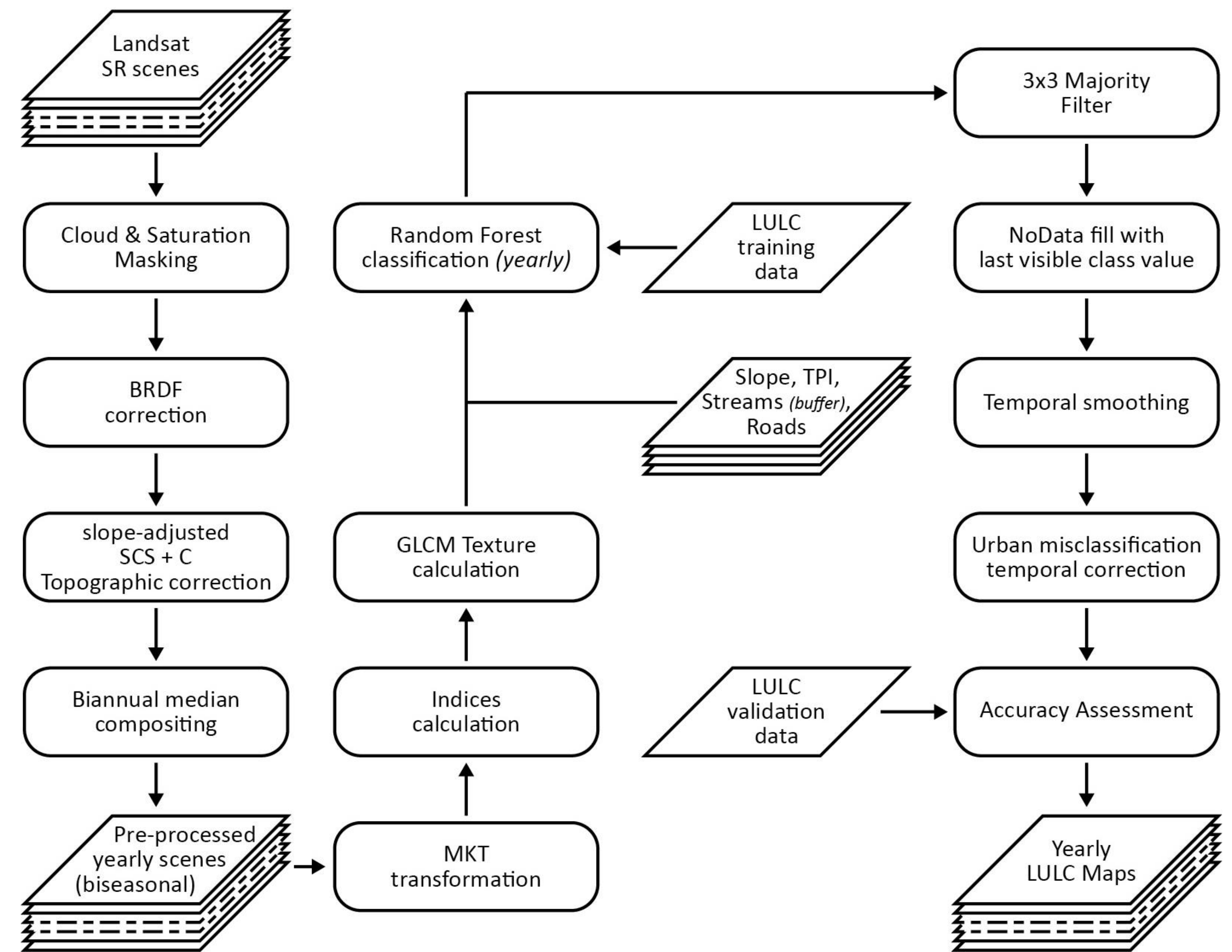


Figure 1 - Google Earth Engine workflow scheme for yearly LULC classification

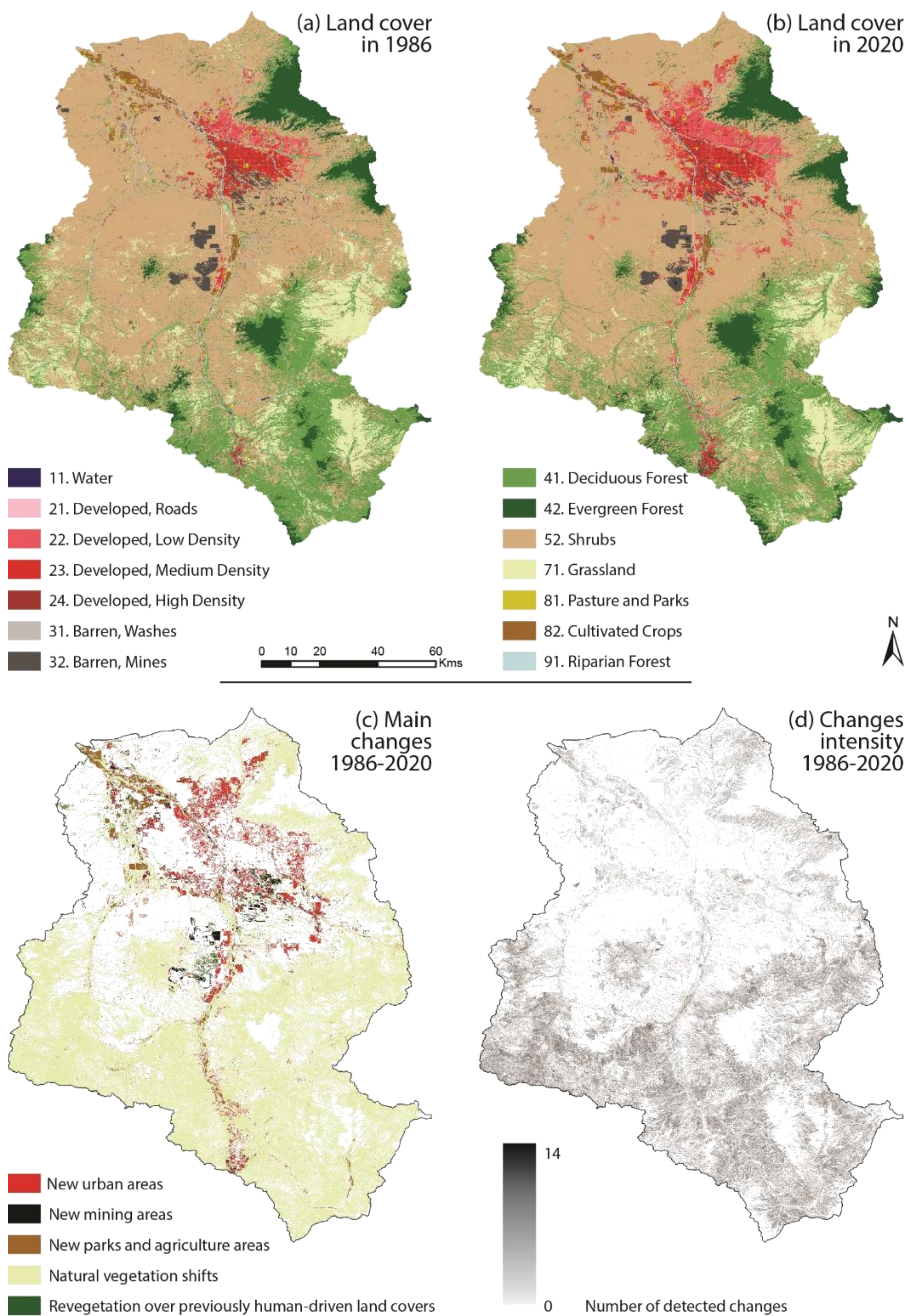


Figure 2 - LULC change dynamics in the Upper Santa Cruz Watershed

RESULTS AND DISCUSSION

We achieved **very good classification results** (yearly Overall Accuracies ranging from 86.7% in 1986 to 96.3% in 2020), allowing us to **precisely quantify trends LULC Changes dynamics** over a 35 year period, and in the future.

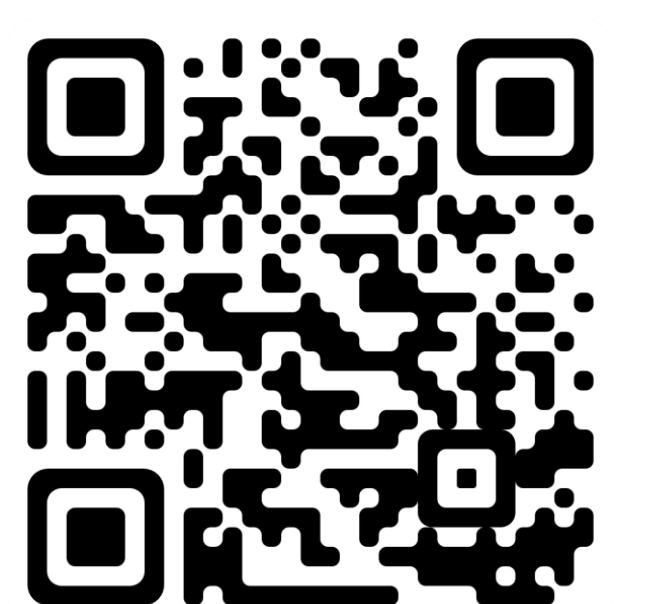
Natural land covers (i.e., shrubs, grasslands, forests and barren washes) are **highly dominant in the region** as they cover $\pm 90\%$ of the watershed. Shifts among natural LULC classes also make up the **vast majority of identified changes** (86.8%). Most commonly observed dynamics are **temporary switches between natural land covers**, which can be explained by different factors, notably **climatic variations** from one year to another, such as prolonged and persistent drought, or the **wildfire and regeneration cycles** impacting forested areas. Still, these LULC classes maintain a **rough balance over the years** at the watershed scale, as most transformations are compensated by opposite trends.

Regarding **human-induced LULC changes**, a few **mining or agriculture lands** have been newly established in some parts of our the region of interest, but their **overall area has decreased** as they are counterbalanced by the natural revegetation of abandoned lands. Albeit less frequent, **anthropic LULC transformations** are most often permanent, especially regarding **conversion to built-up areas** which is the **main driver** of persistent LULC changes in the Tucson area (2.9% of observed changes). Urban development has demonstrated a **steady increase** and has more than doubled (+118.7%) over the last 35 years, and this expansion is clearly oriented towards **low-density development on new lands**, mostly shrubs, rather than densification of existing urban areas (+143.2% vs. +79.1%). This leads to a **leapfrog urbanization**, with 60% this suburbanization occurring away from cities -but close major roads- in new housing communities, often accompanied by green recreational areas such as golfs.

These dynamics are putting an **increasing pressure** to the **scarce water resources** of this arid region and to its fragile ecosystems by **fragmenting species habitats**...

CONCLUSION

We propose here an **automated method** for computing long time series of LULC maps, entirely hosted in GEE to quickly and easily process large amounts of data. While its **performance** has been clearly illustrated with the Tucson area example, this tool is **adaptable to fit other regions of interest** in order to provide critical and timely information on the dynamics of LULC change, with high temporal depth, to decision makers.



<https://doi.org/10.3390/rs14092127>