



# A Fragmentation-Based Analysis of Costa Viola (Southern Italy) Agricultural Terraces

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**Abstract.** Traditional and historic agricultural landscapes cover a significant part of the Italian territory. For these landscapes, the study of change dynamics over a defined time interval is a crucial aspect to monitor their integrity and cultural value and, on the other hand, to set up appropriate strategies to assess their correct management. Terraced agricultural landscapes play an important role in this framework, given their substantial cultural and social value. Because of their artificial creation, this kind of landscape is subjected to continuous changes over time due to the interaction of natural and human factors. To detect the changes that occurred during a time interval of about 60 years, we adopted a fragmentation-based analysis of the terraced agricultural landscape of Costa Viola (Southern Italy). All analyses were conducted in a GIS environment through the free tool Landscape Fragmentation (LandFrag) and the period investigated goes from 1955 to 2014. We analysed the fragmentation of active terraces during three reference years: 1955, 1989 and 2014. A binary raster-based analysis has been conducted for each year according to five fragmentation classes: core, perforated, edge, transitional and patch areas. The dynamic highlighted by the analyses is characterised by the diminution of core areas, representing a stable landscape with no threat of fragmentation, that passed from 300.20 ha in 1955 to just 11.32 ha in 2014, demonstrating an important tendency towards fragmentation of the landscape leading to a gradual disappearance of traditionally cultivated terraces with an increased risk of landslides.

## 1 Introduction

By its definition, the landscape is constantly changing because it results from the interactions between the natural and human components [1, 2]. Rural landscapes are characterised on the one hand by a functional aspect, often related to land use/land cover (LU/LC) and, on the other hand, by a cultural aspect, related to the historical and cultural dimension of the communities that shape the landscapes to meet their needs [3]. Terraced agricultural landscapes play an important role in this framework, given their substantial cultural and social value. Traditional and historic agricultural landscapes cover a significant part of the Italian territory [4]. In European countries, during the last century, a

progressive abandonment of agricultural lands has been highlighted [5–8], especially in terraced systems [9–11], increasing landslide risk [12–15].

For these landscapes, the study of change dynamics over a defined time interval is crucial for monitoring their integrity and cultural value and setting up appropriate strategies to assess their correct management [1]. Several scholars have addressed the detection of terraced agricultural landscapes and their changes over time and the study of typological terraces features [9, 16–23]. LU/LC change analysis provides only a partial picture of the agricultural terrace dynamics. To better understand their evolution trends, it is crucial to detect the spatial configuration of terraced areas through the use of pattern change analysis. Landscape pattern change, i.e., landscape fragmentation, has been linked repeatedly with agricultural productivity and the threat of landscape and habitat loss [24–28]. This research aims to investigate active agricultural terraced system changes analysing their fragmentation dynamics in the study area of the Costa Viola, in the province of Reggio Calabria (Southern Italy) in a time period of about 60 years, from 1955 to 2014. To better understand the dynamics that occurred during this interval, 1989 was chosen as the intermediate year.

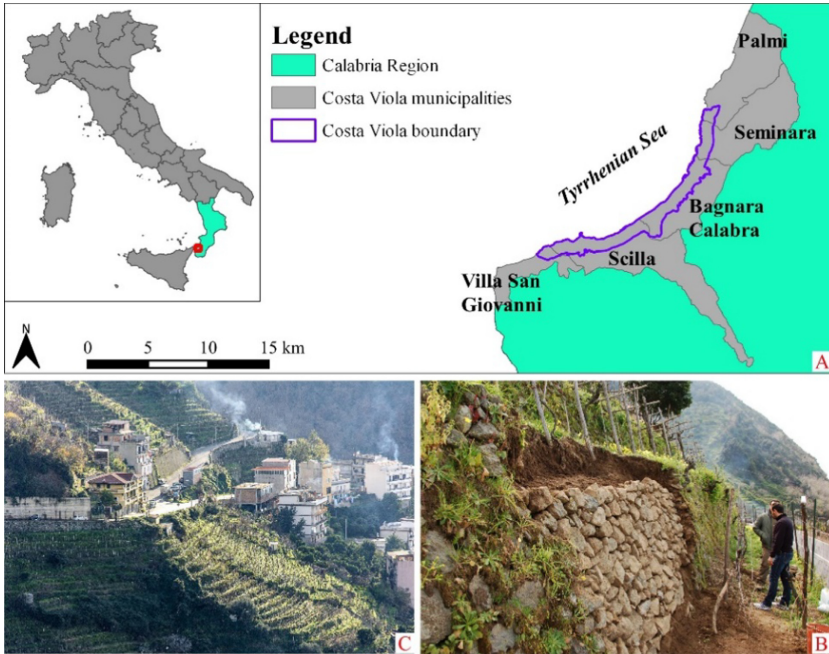
## 2 Materials and Methods

### Study Area

Costa Viola, which literally means “purple coast,” is a narrow coastal strip (1–2 km width) placed in the Tyrrhenian part of the province of the metropolitan municipality of Reggio Calabria (Southern Italy). It covers about 24 km<sup>2</sup>, falling in the administrative territory of five municipalities: Villa San Giovanni, Scilla, Bagnara Calabria, Seminara and Palmi (from South to North - Fig. 1A). The area is characterised by an elevation between sea level and 600 m a.s.l., with very different slope classes (30°–45° is the most representative) and a prevailing North-North-West aspect orientation. Climate is typically the Mediterranean, with drought and hot summers and temperate winters. The terraced systems, dating from the 18<sup>th</sup> century onwards, are characterised by walls, built by specialised craftsmen, completely dry stone (Fig. 1B) and integrated into the anthropic urban environment (Fig. 1C). They are mainly used for vineyards, followed by olive orchards, citrus and to a lesser extent for horticultural crops.

### LU/LC Digitalisation and Fragmentation Analysis

To detect the fragmentation dynamics of the active terraced systems of the Costa Viola, it was first necessary to precisely identify their position and shape in correspondence of each of the investigated years. This has been done, thanks to the characteristic signs of the dry stone walls seen from above, through photointerpretation and manual digitalisation of LU/LC in GIS environment. For 1955, historical B/W aerial photographs have been digitally processed and mosaicked into an orthophoto. For 1989, a digital B/W aerial orthophoto available as a web map service (WMS), by the Geoportal of the Italian Ministry of Environment, has been used as a reference layer for the digitalisation process. For 2014, a WorldView-2 satellite-based image has been used. Moreover, to detect the terraced system, a fourth hierarchical level has been implemented to CORINE Land Cover legend for the agricultural areas. More details about photogrammetric and digitalisation processes can be found in our previous studies [9, 20].



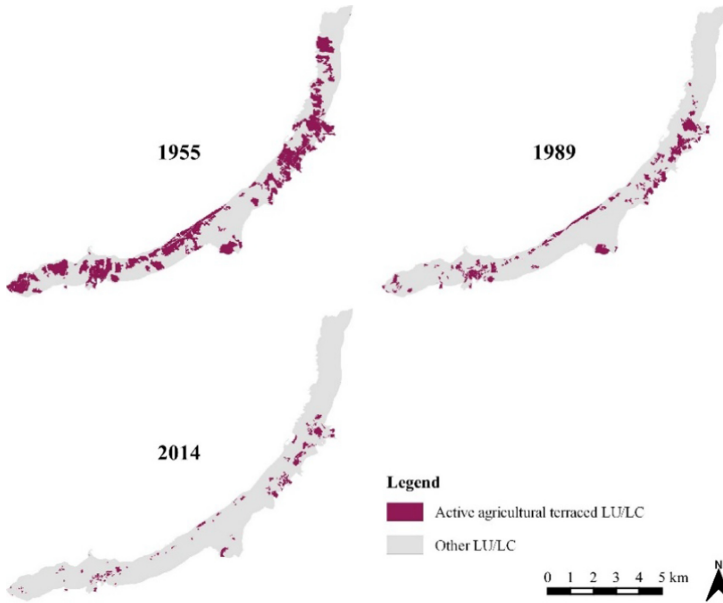
**Fig. 1.** The Costa Viola study area.

All pattern analyses were conducted in a GIS environment through the free tool Landscape Fragmentation (LandFrag) [29]. A binary raster-based analysis has been conducted for each year, rasterising the obtained LU/LC maps. For all active agricultural terraced LU/LC classes the value 1 was assigned, 0 for all other LU/LC classes (Fig. 2). A  $3 \times 3$  moving window has been adopted to detect the 8-neighbourhood pattern of the central pixel, according to five fragmentation classes: i) core, which is the most stable situation in which the central pixel is part of an active terraced area and it is entirely surrounded by pixels with the same LU/LC (active agricultural terraces); ii) perforated, more than 60% of pixels of the moving window belong to an active terraced area and defines the boundary between core and its small perforations; iii) edge, more than 60% of pixels of the moving window belong to an active terraced area and defines the boundary between core and its large perforations or the boundary between active terraces core and other LU/LC areas; iv) transitional, between 60% and 40% of the moving window's pixels are classified as active terraces; v) patch, is the least stable and most worrying situation, representing areas that are active terraces but they are too small to contain core areas.

### 3 Results and Discussions

According to the results of the digitalisation, the amount of the area occupied by active agricultural terraces passed from 813.25 ha in 1955 to 302.59 ha in 1989 and finally decreased to 118.79 ha in 2014 (Fig. 2).

As highlighted in previous studies [9, 20, 30] this abandonment trend, mainly due to a more general abandonment of agricultural activities jointly to a cadastral parcels dissolution process, has mainly affected the most sloping and difficult-to-reach areas.

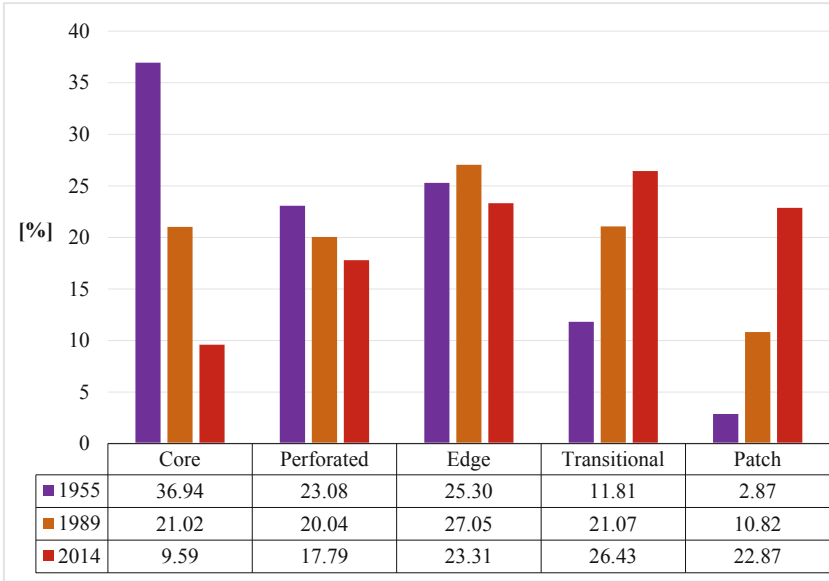


**Fig. 2.** Active agricultural terraced LU/LC maps for each investigated year (1955, 1989 and 2014).

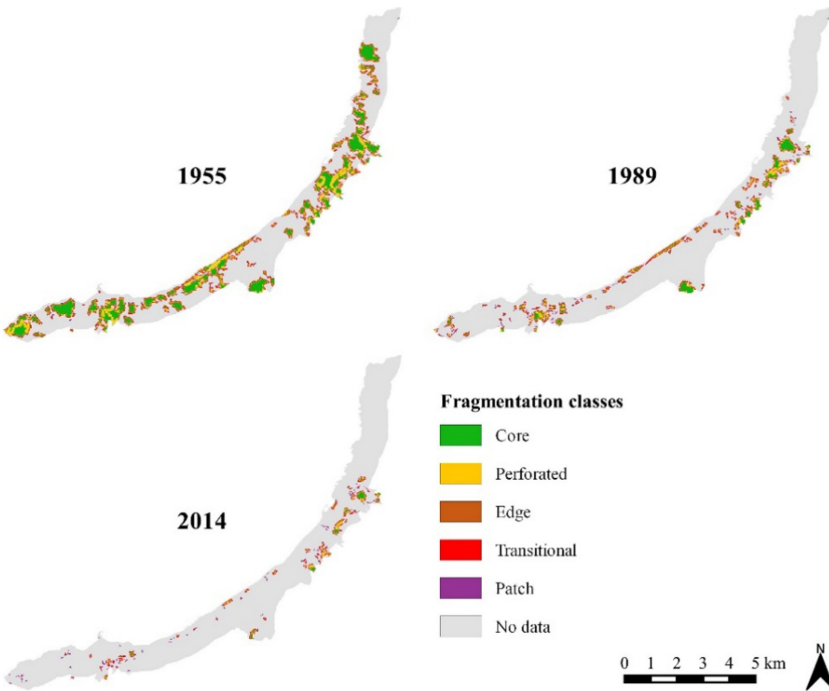
Due to the different extensions of the active terraced areas in the analysed years, the fragmentation analysis results are reported in percentage terms for each class. Results of fragmentation analysis are synthesised in Fig. 3, while Fig. 4 shows fragmentation classes maps.

Core areas, the most stable pattern, registered a continuous decrease passing from 36.94% in 1955 to 21.02% in 1989 and 9.59% in 2014. The decrease of the core areas is combined with the increase of the patch areas that passed from 2.87% in 1955 to 10.82% in 1989 and 22.87% in 2014. These two trends align with the highlighted agricultural terraced areas abandonment and the more general trend of abandonment of agricultural areas. In addition, the dynamic of transitional areas, which increased from 11.81% in 1955 to 21.07% in 1989 and 26.43% in 2014, could be read as a sign of the progressive abandonment of agricultural practices on terraced fields. Analysing the maps in Fig. 3, the same decreasing trend can be highlighted for the core and perforated areas. Instead, the transitional and patch areas share the same increasing trend. Edge areas registered an increase between 1955 and 1989 (25.30% to 27.05%) and decreased between 1989 and 2014 (27.05% to 23.31%).

These results show how the active agricultural terraces, due to fragmentation processes mainly driven by anthropogenic factors, have become less stable over time and therefore more in need of attention. Moreover, the obtained spatial localisation of these areas makes it possible to identify the most critical ones, in order to calibrate the management actions and, where necessary, facilitate access to public funds.



**Fig. 3.** Percentage occupied by analysed fragmentation classes



**Fig. 4.** Fragmentation class maps for each investigated year (1955, 1989, and 2014).

## 4 Conclusion

In this study, we analysed the dynamics of the agricultural terraces of the Costa Viola area, focusing on their pattern changes through a multitemporal raster-based fragmentation analysis. The authors are aware of the possible limitations and constraints of the proposed method that may arise from the use of images from different periods and sources, especially with regard to photointerpretation process, because of their different spatial and spectral resolution. The study highlighted the abandonment of terraced agricultural landscapes and showed the fragility of the remaining terraced areas that are more vulnerable to the fragmentation dynamics that lead to abandonment, thus triggering a dangerous loop. An intelligent and well-calibrated aid program should be put in place to stop this phenomenon, ensuring that funding can be accessed to preserve agricultural activities in these particular traditional landscapes.

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