The cheese stands alone...or does it?

Analyzing the *terroir* of Italian cheese zones

Introduction

Geographical indications of origin (GI), a form of intellectual property, offer cheese producers exclusive rights to place-based name use. GIs are based on the French concept of *terroir*, meaning that there is an inherent connection between the geophysical and climatic properties of a place and the characteristics of an agricultural product. The European Union has a strict certification scheme for GIs, which is communicated through labeling (see above). A Protected Designation of Origin (PDO) offers the strictest level of protection. PDO cheeses require milk inputs and dairy cow feed inputs to be produced within the same area of cheese manufacturing and aging. Italy produces 58 PDO cheeses, with a large concentration of production in the northern part of the country, which is the area of interest in this study (inset map).

PDO certification affords producers a market premium through differentiation from imitation products due to its strong connection with the region's *terroir*.

This study explores the relationship between the geophysical and climatic properties of individual cheese production zones and market price. Primarily, the degree of within-zone homogeneity of these physical properties and market price is evaluated.

Cheese	Price* (€/kg)	Annual Production* (kilograms)	Est. Annual Production Value (€, millions)
Parmigiano Reggiano	9.69	137,000,000	1,327.43
Grana Padano	6.84	184,000,000	1,257.75
Montasio	5.93	6,284,000	37.25
Asiago	5.50	21,400,000	117.69
Provolone Valpadana	5.40	5,427,600	29.32
Gorgonzola	5.30	53,800,000	285.03
Taleggio	4.76	8,873,600	42.26
Quartirolo Lombardo	4.75	3,448,200	16.39

*five year average (2012-2017); Source: CLAL.it

Methodology

Utilizing ten geophysical and climate variables (see input maps below), this study evaluates the homogeneity of these properties within cheese zones. Production zones were created using cheese consortium descriptions of the permitted provinces, municipalities, or geographic boundaries under each PDO registration. These zones vary in size and contiguity, and frequently overlap with each other (Production Zones map).

Homogeneity was addressed through Iso Cluster Unsupervised Classification in ArcMap 10.6.1. The Iso Cluster algorithm creates homogenous clusters of cells with similar values across all input rasters. The algorithm was initially performed with a maximum number of classes (25), sampling interval (10 cells), and minimum class size (20 cells). Several iterations of the classification were run to determine output sensitivity to the three specifications mentioned above.

An iterative model extracted the Iso Cluster results to production zone to derive zonal statistics. Overlapping regions between cheese zones were extracted and compared to each other and to the cheese zones as a whole.

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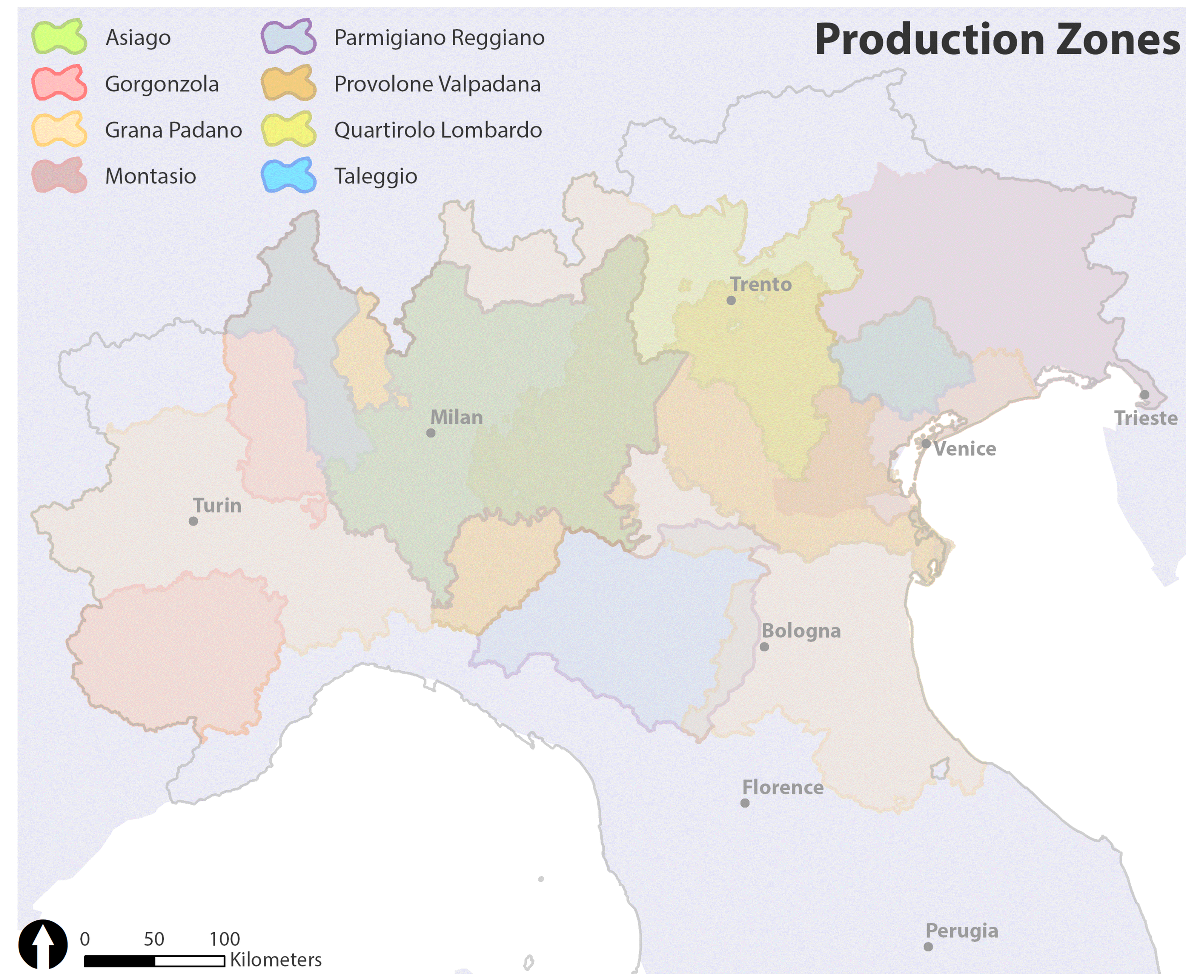
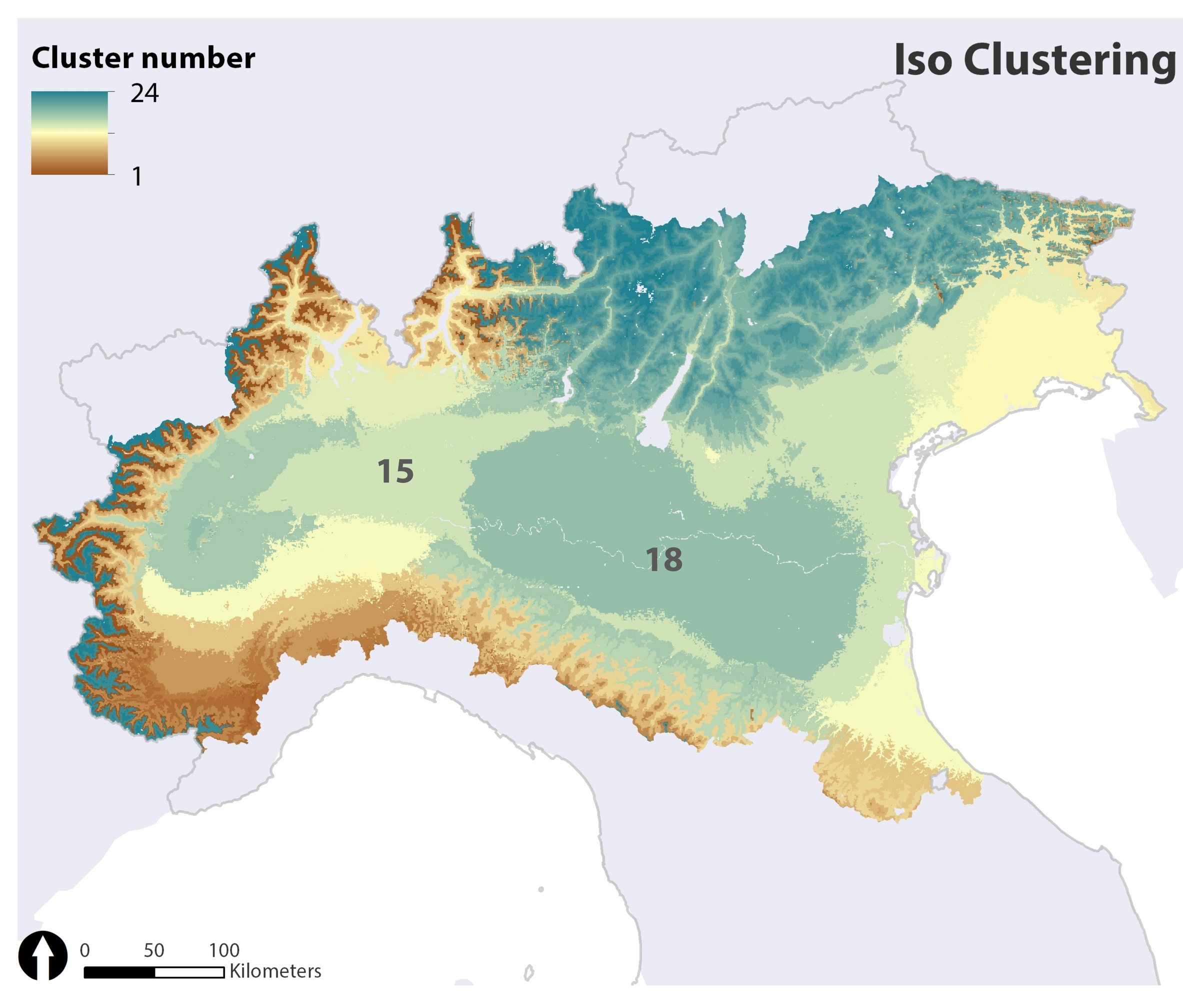
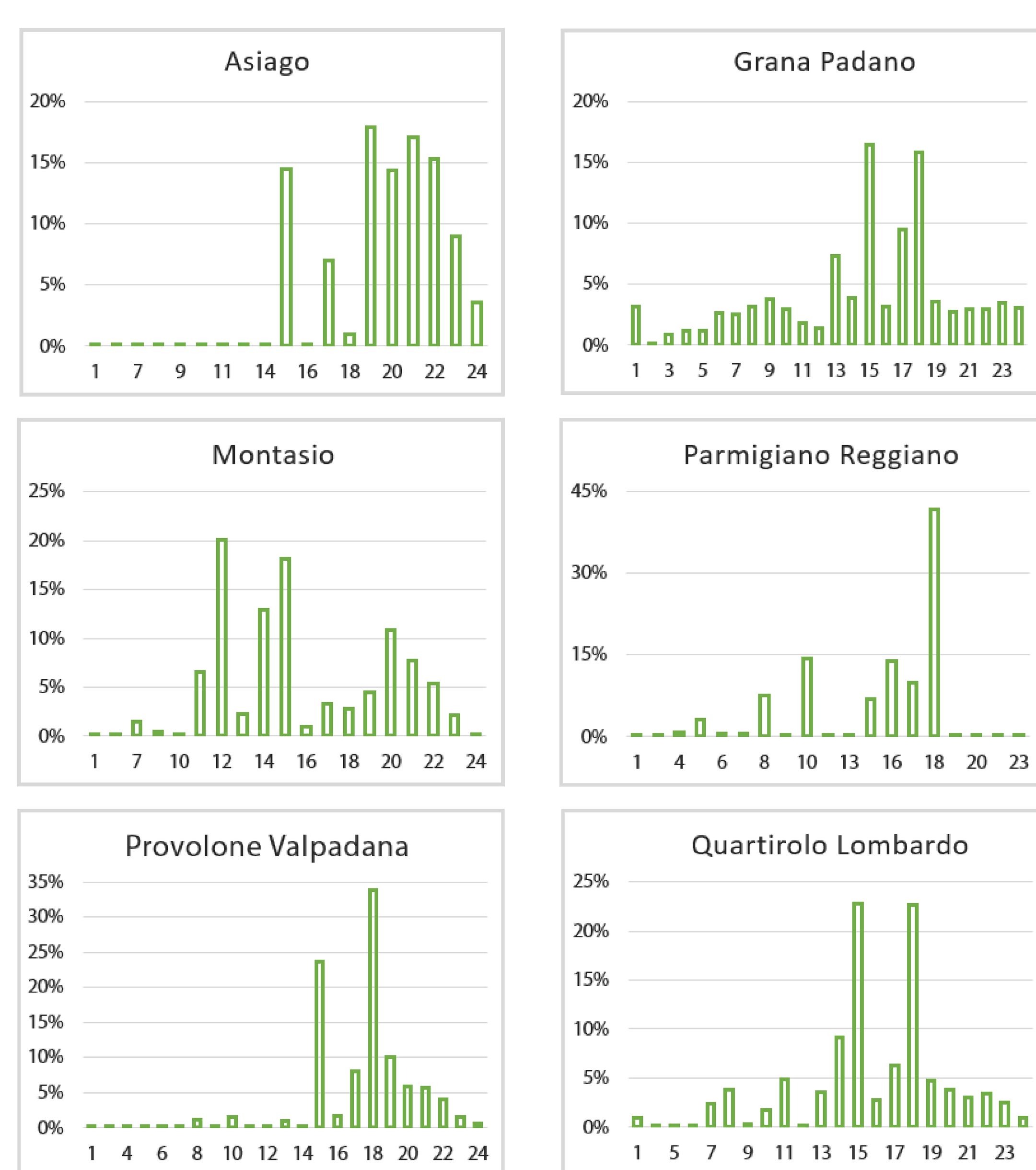
Sources:
Temp & Precip: Fick, S.E. & R.J. Hijmans (2017). Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas.
Bulk Density, AWC, Soil Texture: Ballabio, C., Panagos, P. & L. Monatanarella (2016). Mapping topsoil physical properties at European scale using the LUCAS database.
Elevation: CGIAR-CSI SRTM 90m Database (2008).
Lithology & Land Cover: Wilde, M., Günther, A., Reichenbach, P., Malet, J.-P., Hervás, J., 2018. Pan-European landslide susceptibility mapping: ELSUS V.2.
Production & Price data: CLAL.it (2018). PDO Cheese Production Quantities and Market Prices.
Photos: Wikipedia, asiagocheese.it

Results







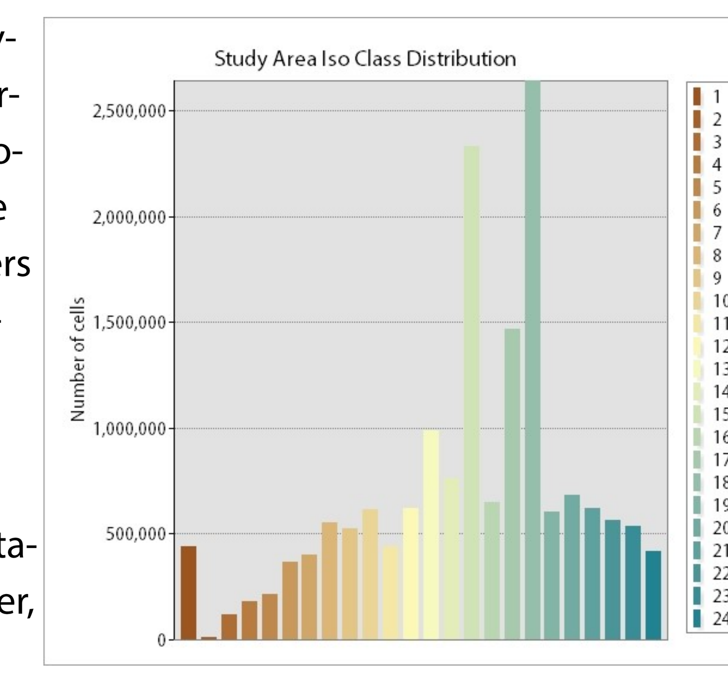
Note: Gorgonzola distribution similar to Grana Padano; Taleggio distribution similar to Quartirolo Lombardo

A total of 24 clusters were identified in the Iso Clustering algorithm. Density distributions of the Iso clusters in each cheese zone are found in the charts below, demonstrating the variability of clusters within each zone.

Parmigiano Reggiano had the highest fraction of its production zone in a single cluster (0.41) compared to all other cheeses. The largest cluster, Cluster 18, is an area where several cheese production zones overlap (e.g. Parmigiano Reggiano, Grana Padano, Provolone Valpadana, Quartirolo Lombardo). This region is characterized by a high degree of homogeneity of geophysical and climatic properties due to its location in a valley with little variation in elevation. Additionally, most of the land is in feed crop production for local dairy cattle.

Parmigiano Reggiano is the most expensive cheese per kg of the 8 selected in this study. It is more than twice the price of the lowest-priced cheese (Quartirolo Lombardo), though they both have large shares of Cluster 18 in their production zones.

Cluster 15 also spanned several production zones, encircling Cluster 18 outwards towards the mountains. There is greater variation in clusters within the mountainous regions, largely due to elevation variability. The smaller class sizes in these regions capture variation in precipitation, temperature, land cover, and soil properties.



Discussion

Larger minimum class sizes reduced the number of classes calculated by the Iso Clustering algorithm. However, a doubling of the class size (20 to 40 cells) only reduced the number of classes from 24 to 23. Several patterns in cluster distribution were derived from this analysis:

- Quartirolo Lombardo and Taleggio had nearly identical cluster distributions and differ in market price by €0.01.
- Grana Padano, with the second highest market price, has a wide dispersion of clusters within its production area, with its largest fraction in a single cluster (0.16) being the lowest of any of the cheeses. Wide dispersion over clusters is likely due to its production zone being the largest.
- Gorgonzola and Taleggio are the only non-contiguous production zones, and have lower market prices than most contiguous zones. Contiguity may be associated with a higher degree of homogeneity.
- Provolone Valpadana, with the second highest fraction of its production zone in a single cluster (0.34), has a similar market price to less homogenous production zones (e.g. Gorgonzola and Asiago).
- The 3 smallest production zones (Asiago, Parmigiano Reggiano, & Montasio) have higher market prices than most larger zones. These cheeses also have smaller overlaps in production zone with other cheeses. These cheeses all have the same number of clusters (19) within their production zones, while all other zones have 22 or more clusters.

There appears to be little validation of the connection between market premiums afforded to PDO producers and the inherent *terroir* properties of their production zones. Market price may be weakly associated with smaller production zones that have fewer clusters. Cheese aging length, export volume, and regional sufficiency for dairy cattle feed could be explored in future research to evaluate other determinants of market price.

Geophysical & Climatic Variables