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An emerging Longevity Blue Zone in Sicily: The Case of Caltabellotta and the Sicani Mountains

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Abstract: Blue Zones (BZs) are regions across the world associated with exceptional human longevity, where individuals routinely live into their 90s and beyond. These areas share distinct lifestyle and environmental factors that promote healthy aging. The established BZs include Sardinia, Okinawa, Ikaria, and Nicoya, while several "emerging" BZs have been reported in various parts of the globe. This study investigates an area in Sicily for similar longevity patterns. Demographic data from Italy National Institute of Statistics and local civil registries identify the municipality of Caltabellotta, home to approximately 3,000 residents, and the nearby *Sicani Mountains* as a potential emerging BZ. The area exhibits a significantly higher prevalence of nonagenarians and centenarians compared to national and regional averages. Between 1900 and 1924, the proportion of residents aged 90 and above rose from 3.6% to 14% with one out of 171 individuals born in Caltabellotta during this period reaching the age of 100. Historical, dietary, environmental, and sociocultural characteristics align with known BZ traits, including adherence to the Mediterranean diet, physical activity through agrarian routines, strong social cohesion, and minimal environmental pollution. A comparative analysis with the validated Sardinia BZ supports the hypothesis that this Sicilian area may represent an emerging longevity hotspot. Further multidisciplinary investigation is warranted to substantiate these findings.

Keywords: longevity; Blue Zones; Sicily; health; environment

1. Introduction

Human longevity has long fascinated scholars across multiple disciplines, including gerontology, public health, and anthropology. Although global life expectancy has risen consistently over the last century [1], certain geographical pockets, known as "Blue Zones" (BZs), stand out for their remarkably high concentration of individuals living well into their 90s and beyond [2]. The concept of BZs was introduced more than two decades ago following the rigorous identification of a long-lived population in inland areas of Sardinia, Italy [3]. Since then, BZs have become focal points for studying the interplay of genetics, lifestyle, and environmental factors contributing to human longevity [4].

Following the formal recognition of the Sardinian BZ [3], other communities with similar demographic patterns have been discovered, including populations on the island of Okinawa, Japan [5], Ikaria, Greece [6], and the Nicoya Peninsula, Costa Rica [7]. These regions consistently show demographic indicators of longevity that significantly exceed national averages, thus supporting their classification as established BZs. Other locations, such as the Cilento region in Southern Italy

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[8–10], a municipality in The Netherlands [11], and the island of Martinique in French Antilles, one of the overseas departments [12] have been identified as potential or emerging BZs, but conclusive evidence remains pending. A few years ago, a Chinese region was also proposed as a possible BZ based on the proportion of ninety-year-olds [13]. By contrast, some regions considered potential candidates, including Menorca in the Balearics [14] and Southern California [15], have failed to meet the criteria for exceptional longevity. Notably, Loma Linda in California is often included among BZs despite a lack of comprehensive demographic validation [16].

Sicily, the largest Mediterranean island, is renowned for its complex demographic and cultural history shaped by millennia of migration and trade [17]. The island has been influenced by the Phoenicians, Greeks, Romans, Byzantines, Arabs, Normans, and other populations, each leaving an indelible mark on its cultural landscape [18]. The island population is also known for its adherence to a traditional Mediterranean diet, characterized by a high consumption of fruits, vegetables, legumes, and olive oil [19]. Despite its similarities to Sardinia in terms of diet and geography, Sicily has been less extensively studied for the presence of longevity clusters [20], although evidence of individuals who have reached extreme age and recent local surveys [21,22] suggest that inland Sicilian villages may share features with known BZs.

In recent years, specific areas of inland Sicily have attracted attention for demographic patterns that seem to mirror those of established BZs: small, rural towns exhibiting a disproportionately high number of nonagenarians and centenarians [20,21]. Many of these individuals not only reach advanced ages but also maintain good cognitive and physical function, continue to follow traditional dietary and lifestyle practices, and adhere strongly to the Mediterranean diet [19,21–24]. Despite these promising indicators, systematic research into the potential existence of longevity hotspots in Sicily remains limited. Much of the available data is anecdotal or derived from municipal civil registries, lacking the epidemiological consistency required to confirm such claims.

Furthermore, much of the existing literature on longevity primarily focuses on genetic or clinical determinants, while the synergistic role of environmental and sociocultural factors remains less explored. An interdisciplinary approach integrating community-based demography, environmental science, and nutritional epidemiology is therefore needed to uncover the drivers of healthy aging in this region.

The present study investigates whether specific areas in Sicily, particularly the *Sicani Mountains*, exhibit characteristics of an emerging BZ. We compared the longevity metrics of this region with those of the validated BZ from Sardinia, since Sardinia represents a valid point of comparison for investigating the environmental, dietary, and sociocultural factors that may promote healthy aging. The findings also offer a basis for reflecting on broader conceptual and methodological challenges involved in defining a region of exceptional longevity when observed in an early stage of development.

2. Materials and Methods

2.1. Data Sources

To investigate the presence of potential longevity hotspots in Sicily, we employed a two-step approach based on (i) official national demographic statistics and (ii) local civil registry records from individual municipalities. As the identification of an area of "exceptional longevity" must be consistently based on demographic data, we proceeded as follows: We accessed population data through the Italian National Institute of Statistics (ISTAT) online database [25] by selecting the "Islands" area, the "Sicily" region, and subsequently, each province on the island. For every municipality, we retrieved the total population and the number of resident individuals aged 90 and over (90+) and those aged 60 and over (60+), and calculated the ratio 90+/60+ [26,27]. Using these data, we generated an initial geographical map representing the raw distribution of the proportion of residents aged 90 and over relative to the population aged 60+. Visual inspection of this map, as well as resorting to spatial statistical analysis, allowed us to detect clusters of municipalities in which the

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prevalence of nonagenarians was notably higher than in surrounding areas. Among the identified clusters, we selected the one with the highest 90+/60+ ratio for a more detailed investigation. To avoid choosing municipalities that are too small, where the presence of long-lived individuals may be coincidentally high, we listed all 391 Sicilian municipalities in decreasing order according to the 90+/60+ ratio and selected the first ones that exceeded 3,000 inhabitants.

Within the municipality exhibiting the highest 90+/60+ ratio, we surveyed the demography retrospectively. Using local civil status registers, we reconstructed annual birth cohorts from 1900 to 1924 and calculated, for each birth year, the proportion of individuals who had reached the age of 90. This enabled us to determine the year-specific probability of attaining age 90 among those born in the municipality during the early 20th century **[28]**.

2.2. Statistical Analysis

We assumed a null hypothesis, that no areas of exceptional longevity exist in Sicily. To test this hypothesis, for the 391 municipalities we calculated the 90+/60+ ratio. To better visualize and interpret spatial patterns, we generated a smoothed distribution map using Kernel Density Estimation (KDE), a non-parametric technique widely used for spatial data interpolation [29]. KDE estimates the density of long-lived individuals across space without assuming an underlying distribution. The general KDE formula is as follows:

$$\lambda(m) = \sum_{i=1}^{n} \frac{1}{\pi r^2} k\left(\frac{d_{is}}{r}\right)$$

where λ(m) is the estimated longevity density at a given municipality m, n the number of municipalities considered, r is the kernel bandwith (i.e. the smoothing radius), d_{is} the distance between municipality i and the target municipality m, k the kernel function, modelled as a non-negative function of the ratio between d_{is} and r. The bandwidth parameter r was optimized through iterative testing to balance map smoothness and spatial accuracy. Next, the degree of global spatial autocorrelation was calculated for the 90+/60+ ratio according to Moran's I index with inverse distance weighting, using the open–source R software (http://www.rproject.org/). Moran's I is a measure of spatial autocorrelation developed by Patrick Alfred Pierce Moran [30] and defined as:

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2}$$

where I represents the Moran's index, N the total number of spatial units (municipalities), X_i and X_j the 90+/60+ ratio in the municipality with coordinates i-th and j-th; $\bar{X}$ is the average of 90+/60+ ratio across all municipalities; w_{ij} is the spatial weight matrix which represents the adjacency relationships of the spatial units.

Spatial autocorrelation reflects the overall distribution of a variable among adjacent locations in space. Moran's I index assumes values > 0 when the corresponding variable is spatially clustered and values < 0 when it is dispersed. Its values were transformed into Z−scores to test the null hypothesis that the spatial autocorrelation of any variable included in the study was zero; when values are greater than 1.96 or smaller than −1.96 the null hypothesis is rejected, and the variable is considered spatially autocorrelated at the 5% threshold. The next step was to perform hotspot analysis to identify areas with significant clustering of high 90+/60+ ratio. The Getis-Ord Gi* statistic was used according to Getis and Ord [31]. The formula is:

$$G_i * = \frac{\sum_j w_{ij} X_j - X \sum_j w_{ij}}{\sqrt{\frac{\sum_j X_j^2}{N} - X^2} \sqrt{\frac{N \sum_j w_{ij}^2 - \left(\sum_j w_{ij}\right)^2}{N - 1}}}$$

where the symbols are the same as the Moran's formula. The Getis-Ord Gi* statistic is typically standardized into a Z-score, allowing statistical significance testing (e.g., p-values).

Next, we estimated the probability of reaching age 90 for each annual birth cohort in the selected municipality between 1900 and 1924. This figure was calculated as the ratio of individuals aged 90+

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to the number of births in the same year, based on civil registry data. For comparative purposes, we analysed equivalent data from the Sardinian BZ, specifically the seven municipalities previously identified as having the highest longevity in Sardinia [3]. For each calendar year, we computed the mean probability of reaching age 90 across these municipalities, along with standard deviations and 95% confidence intervals (CI), using the following formulas:

$$\text{Lower limit} = \hat{p} - z \times \sqrt{\frac{\hat{p} \times (1-\hat{p})}{n}} \qquad \text{Upper limit} = \hat{p} + z \times \sqrt{\frac{\hat{p} \times (1-\hat{p})}{n}}$$

where p is the probability of reaching 90 years and z is the critical value that depends on the confidence level, assumed to be equal to 1.96 [32]. The mean values of the probability of reaching 90 years of age for each person born in the selected municipality from 1900 to 1924 were plotted together with the 95% confidence interval calculated for the seven top longevity municipalities of Sardinia. All analyses were in Excel and SPSS 22 (Chicago, USA).

3. Results

3.1. Longevity Patterns Across Sicily

As of 2025, Sicily comprised 391 municipalities, divided between metropolitan cities and free municipal consortia, within nine provinces [25]. The percentages of residents who are 90+ years old, 60+ years old and their ratio in the nine provinces of the island are shown in Table 1.

Table 1. Number of nonagenarians, sexagenarians, and 90+/60+ ratio (%) in the nine Sicilian provinces in 2025.

Province	No. of residents [1]	Number of 90+ (%)	Number of 60+ (%)	90+/60+ ratio (%)
Agrigento	408,059	5,644 (1.383)	129,974 (31.851)	4.342
Caltanissetta	244,913	2,987 (1.219)	77,341 (31.579)	3.862
Catania	1,068,563	12,205 (1.142)	317,147 (29.679)	3.848
Enna	152,387	2,342 (1.537)	51,059 (33.506)	4.587
Messina	595,948	8,623 (1.447)	198,906 (33.376)	4.335
Palermo	1,194,439	14,505 (1.214)	365,727 (30.619)	3.966
Ragusa	320,976	3,576 (1.114)	91,993 (28.660)	3.887
Siracusa	382,690	4,054 (1.059)	119,177 (31.142)	3.402
Trapani	411,396	5,709 (1.388)	133,256 (32.391)	4.284

[1] Source: ISTAT, Italian National Statistics Institute (https://demo.istat.it/).

Figure 1a illustrates the raw distribution of the percentages for age 90 and older in the 391 Sicilian municipalities, and Figure 1b shows the distribution of the same percentages smoothed through the calculation of the KDE (Figure 1a and b). The longevity area are the mountainous region previously identified through the analysis of reduced mortality between the ages of 80 and 100 [20].

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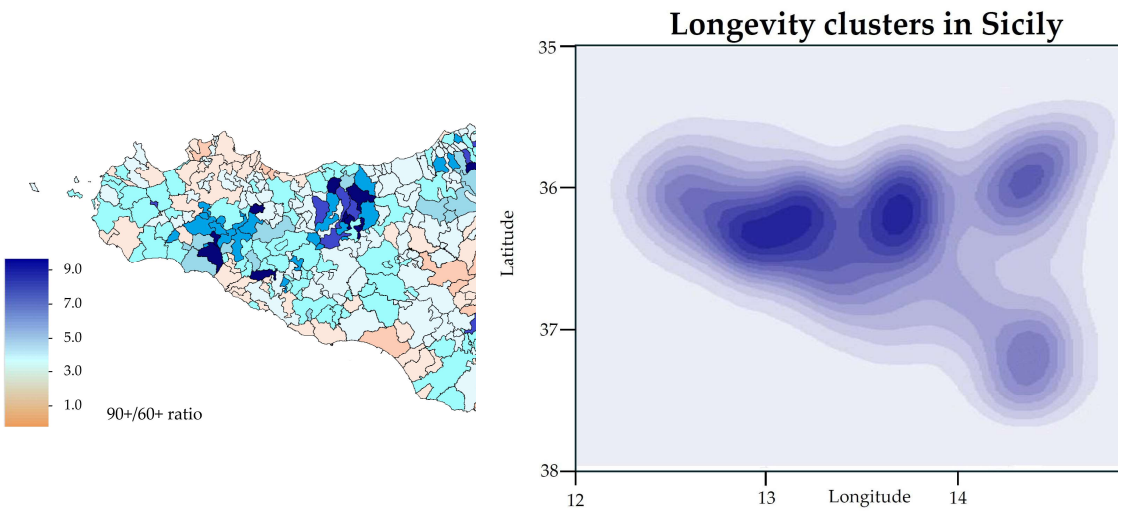

(**a**) (**b**)

Figure 1. (**a**) Map of Sicily showing the distribution of 90+/60+ ratio; (**b**) Map of Sicily showing the smoothed 90+/60+ ratio.

The KDE mapping revealed three main longevity clusters: in the *Sicani Mountains* (west), in the Madonie area (north-central), and in north-eastern Messina province (Nebrodi). These areas share characteristics such as remoteness, low urbanization, and traditional agrarian lifestyles.

The municipalities with the highest value of the 90+/60+ ratio are depicted in descending order in Table 2.

Table 2. Sicilian villages with the highest value of the 90+/60+ ratio in descending order.

N.	Municipality	Province	Population *	90+	60+	90+/60+
1	Novara di Sicilia	Messina	1,131	40 (3.537)	437	9.153
2	Geraci Siculo	Palermo	1,684	55 (3.266)	613	8.972
3	Bompietro	Palermo	1,153	45 (3.903)	503	8.946
4	Sant'Angelo Muxaro	Agrigento	1,170	44 (3.761)	492	8.943
5	Giuliana	Palermo	1,680	61 (3.631)	697	8.752
6	Caltabellotta	Agrigento	3,184	103 (3.235)	1,194	8.626

* Source: ISTAT, Italian National Statistics Institute (https://demo.istat.it/).

Supplementary Table S1 reports the population values, number of ninety-year-olds, sixty-year-olds and 90+/60+ ratios only for the municipalities comprised in the *Sicani Mountains* area. It can be noted that the two municipalities of Caltabellotta and Giuliana stand out, with values of 90+/60+ ratios significantly higher than the regional average.

3.2. Focus on the town of Caltabellotta

Among the top longest-lived Sicilian municipalities, we selected Caltabellotta as the target municipality due to its highest 90+/60+ ratio and a population size exceeding 3,000 inhabitants. This approach minimized the risk of including municipalities with a spuriously high number of nonagenarians due to random variation resulting from small population size. The municipality with these characteristics was Caltabellotta in the province of Agrigento, part of the westernmost longevity cluster on the island.

The municipality of Caltabellotta is located atop the *Sicani Mountains* in southwestern Sicily at coordinates 37°34′32″N, 13°13′06″E, sits at an altitude of 949 meters above sea level. As of January 1, 2025, it had 3,184 inhabitants with a density of nearly 24 inhabitants per square kilometre. The town

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is one of the island oldest continuously inhabited settlements, with roots tracing back to the ancient Sicanian civilization, predating Greek colonization [33]. Throughout history, it has absorbed layers of Greek, Roman, Arab, Norman, and Spanish influences. The town isolation and rugged terrain historically limited outside contact, fostering a stable population with deep intergenerational ties. Its agrarian lifestyle, based on olive oil, legumes, vegetables, and goat products, reflects the traditional Mediterranean diet long linked to longevity [34]. Traditional practices, manual labour, seasonal rhythms, and social rituals persisted well into the 20th century, contributing to low stress levels and low active aging.

The municipality administration provided access to the civil status registers from 1900 to 1924. For each calendar year, the number of newborns who attained age 90 and over was divided by the total number of newborns. By considering an interval of 25 years, we minimized the instability of the rate of long-livers, as was done in the case of Sardinia [3]. The proportion of 90+ and 100+ individuals in the aforementioned period was compared with that of the Sardinian long-lived area already verified. To do this, we used the data of the seven Sardinian municipalities with the highest longevity, of which the distribution of nonagenarians and centenarians in the time interval 1900–1924 was known. Caltabellotta showed a 90+/60+ ratio of 8.626% in 2025, which is double the regional (4.017%) and provincial (4.342%) average.

By consulting the Caltabellotta civil status registers between 1900 and 1924, we identified a total of 472 persons of both sexes aged ≥ 90 years out of a total of 5,319 born in the municipality, while in the seven municipalities of the Sardinia longevity area, the figures were 1163/9233 (Supplementary Table S2). From the comparison between the two locations, it emerges that the share of 90-year-olds in Caltabellotta during the specified interval is equal to 8.9%, while in the Sardinia BZ area, it is equal to 12.6%. Therefore, the percentage of 90+ individuals in Caltabellotta is approximately 30% lower than in a municipality of the Sardinia BZ. However, despite the lower overall proportion, the rate falls within Sardinia BZ 95% confidence interval.

Figure 2 illustrates the variation in the proportion of newborns who attained age 90 from 1900 to 1924 in Caltabellotta compared with the corresponding variation in the Sardinian long-lived area. The entire curve for Caltabellotta can be noted in the lower part, yet within the confidence interval. The blue curves indicates the ± 2SD confidence interval around the mean of the proportion of individuals who reached the age of 90 years in the Sardinia BZ.

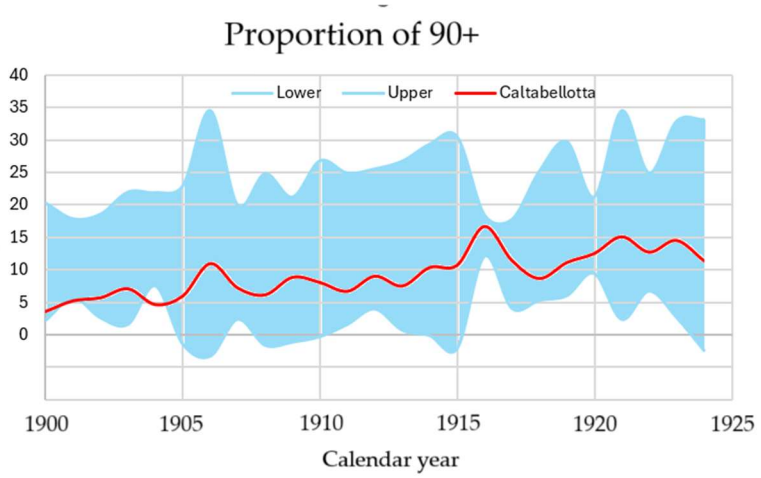

Figure 3. Proportion of newborns who attained age 90 in Caltabellotta in the period 1900–1924 (red line), compared with the 95% confidence intervals for the Sardinian BZ in the same period (blue lines).

To further evaluate the proportion of the oldest old in Caltabellotta, we counted the number of individuals born between 1900 and 1924 who became centenarians. A total of 31 individuals who reached age 100 were identified, corresponding to a birth rate of one future centenarian approximately every 171 births. As the definition of the Sardinian Blue Zone in 2004 referred to 90

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centenarians out of 17,865 births (equal to 1:198 births) [3], the probability of becoming centenarians in Caltabellotta is fully compatible with that of a validated BZ. The comparison between the proportion of centenarians born in Caltabellotta and in the Sardinian BZ was carried out for each single calendar year, and the difference was tested by χ^2. The difference was not significant except for those born in 1907, in whom the proportion of centenarians in Caltabellotta was significantly lower than in the Sardinian Blue Zone ($p = 0.034$).

4. Discussion

Based on official statistics, the findings of this study indicate that the population of Caltabellotta, located near the *Sicani Mountains* area of Sicily, exhibits the characteristics of an emerging BZ area. Therefore, we can confidently reject the null hypothesis that no areas of exceptional longevity exist in Sicily. Compared to the Sardinia BZ, individuals born in Caltabellotta have a probability of reaching 90 years of age that not only exceeds national and regional averages but also falls within the confidence interval observed in the Sardinian BZ municipalities.

The 90+ ratio, expressing the probability of reaching age 90, has progressively increased across the birth cohorts from 1900 to 1924. In this context, it is justifiable to describe the Caltabellotta population as an "emerging Blue Zone," as its demographic trajectory increasingly aligns with regions of recognized longevity status.

Although criticisms have been raised about the reliability of demographic registers in BZs, which calls into question the existence of BZs themselves, especially in poorer areas with high illiteracy rates [35,36], in the case of Caltabellotta, our survey of existing registers confirmed the reliability of the information contained therein, comparable to that of Sardinia. However, when interpreting these data, certain limitations must be considered. First, the number of individuals aged 90 and above recorded in the civil status registers may be underestimated. The dataset includes several incomplete records—specifically, individuals whose birth in the municipality is documented, but whose death is unregistered. These may include residents who passed away in the town without a formal registration of death, or more likely, those who died elsewhere and whose death was not reported back to the municipality of birth. Hence, the true level of longevity in Caltabellotta may be higher than currently reported. However, in line with the idea that the longevity of this population is likely experiencing an ascending phase, it can be hypothesized that in the near future, the community could fully assume the characteristics of an established Blue Zone. More comprehensive research that systematically addresses these data gaps would be needed for a more accurate estimation.

Regarding centenarians (100+ years), this is a stricter metric of longevity previously used to characterize the Sardinian longevity. Between 1900 and 1924, at least 31 individuals born in Caltabellotta achieved centenarian status, as validated through civil registry data. Among them, Mr. Antonino Turturici (January 18, 1912–September 23, 2021), a semi-supercentenarian, was notably the oldest living Italian male at the time of his death [37]. His family also included several other long-lived individuals, with at least three siblings surpassing age 90. In the town of Chiusa Sclafani, located only 25 km from Caltabellotta, Mrs. M.S.V.B. (December 2, 1904–January 14, 2016) lived 111 years and 43 days and was reported in the official list of Italian supercentenarians. Moreover, Ms. F.F., who is 113 years old, was born in Sciacca (and currently lives in Agrigento), just 20 km from Caltabellotta. Such "sentinel" longevity cases are often considered marks of exceptional longevity clusters and strong indicators of a broader community trend [14]. Similarly, the presence of two supercentenarians whose ages had been validated has been reported in the village of Isnello, located in the second longevity cluster identified in Sicily (Caruso, manuscript submitted). Apart from the exceptional case of Mr. Turturici in Caltabellotta, the presence of 31 centenarians out of 5,319 births indicates a frequency of just over 1 centenarian every 171 births, which is not far from the value of 1:198 recorded in the Sardinian Blue Zone [3]. Furthermore, some of Caltabellotta centenarians were family-related: two were sisters, and another pair was a married couple. Although this represents a small sample,

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such kinship patterns suggest shared environmental or lifestyle factors that may promote longevity within the broader community.

In most BZs, except Okinawa, the longevity of men is comparable to that of women [3]. However, this trend was not observed in Caltabellotta, where 23 of the 31 centenarians were women, a finding aligned with the well-known gender gap in survival observed in most aged populations [38].

The identification of a possible BZ in western Sicily, confirming previous research [23], naturally raises questions regarding the underlying determinants of this phenomenon. Longevity is commonly viewed as a proxy for healthy aging, and areas with high concentrations of long-lived individuals are often considered to possess unique combinations of protective factors that slow the aging process across large segments of the population. These factors, broadly categorized into genetic, environmental, and cultural domains—are generally thought to apply both at the individual and population levels [39].

4.1. Genetic Factors

Longevity is not determined solely by genetics. This message made headlines worldwide a few years ago following a collaborative study between statisticians from Ancestry and Calico Life Sciences. By analysing family trees encompassing 400 million individuals, with detailed records on birth and death dates, locations, and family ties, the study concluded that genetic factors account for less than 10% of lifespan variability [40]. However, this large-scale study examined the genetic influence on lifespan broadly and did not specifically focus on exceptional longevity, as very few families with centenarians were included in the analysis. On the other hand, evidence is compelling that adopting a healthy lifestyle can significantly increase life expectancy in the general population [41]. A study published last year, which evaluated the habits of more than 276,000 U.S. veterans, revealed that adopting eight healthy behaviours could extend lifespan by up to 24 years. These behaviours included maintaining a balanced diet, engaging in regular physical activity, getting adequate sleep, managing stress effectively, cultivating strong social relationships, and avoiding smoking, opioid abuse, and excessive alcohol consumption [42]. According to the researchers, veterans who adhered to all eight behaviours could expect to live up to approximately 87 years, nearly a decade longer than the current average life expectancy in the United States. As age advances, particularly beyond 80 years, genetics appears to play an increasingly significant role in maintaining health and longevity. Among centenarians, genetic influence is estimated to account for up to 33% of longevity in women and 48% in men [43].

In the case of Sicily, genetic studies have shown a relatively homogeneous population structure. No significant differences have been found between the western and eastern parts of the island, and overall gene frequency variations suggest that Sicily acts as a single genetic unit—unlike Sardinia, which is considered a genetic isolate [44]. Studies on uniparental markers, such as mitochondrial DNA and the Y chromosome, further confirm a high degree of intrapopulation variability which, however, does not cluster into genetically distinct subgroups [44]. These findings suggest that the longevity in Caltabellotta is unlikely to be driven by genetic uniqueness, reinforcing the relevance of environmental and lifestyle influences.

4.2. Environmental Factors

Environmental factors may offer a particularly compelling explanation. Several studies have provided evidence that altitude, soil type, and vegetation biodiversity are major environmental factors influencing the longevity of nearby populations. Most globally recognized longevity hotspots, Okinawa being a notable exception, are located at moderate altitudes. For instance, the seven Sardinian municipalities with the highest longevity indices are situated between 480 and 1,000 meters above sea level [3]. Living at such elevations may promote higher daily energy expenditure, more robust metabolism, and lower accumulation of body fat, all of which contribute to healthier aging profiles [45]. The *Sicani Mountains* are a vast area straddling the provinces of Agrigento and Palermo,

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largely composed of a hilly strip interspersed with vast plains occupied by arable and uncultivated land and pastures, while the mountainous area (over 800 m a.s.l.) is characterized by sheer cliffs, mostly made up of carbonates. This hilly area, typically with low population density and slight economic delay, offers a unique case for examining how environmental and lifestyle variables may interact to promote long-term health. Additionally, the natural environment, marked by clean air, limited industrial activity, and biodiversity-rich landscapes, may contribute to a reduced allostatic load, i.e., the cumulative physiological wear and tear on the body due to chronic exposure to stressors [46], thereby supporting both physiological and psychological resilience over time. The mountainous nature of all four *Sicani* municipalities with the highest 90+/60+ ratio is worth noting (altitude Caltabellotta 949, Giuliana 710, Chiusa Sclafani 658, and Bisaquino 744 mt. a.s.l.) comparable to that of similar long-lived municipalities in the Sardinia region and elsewhere. Caltabellotta, located at 949 meters above sea level, falls within this beneficial altitude range. While cardiovascular benefits from high altitude are generally associated with elevations above 1,500 meters [47], even moderate elevations such as those found in the *Sicani* region may promote active lifestyles and reduce environmental stressors [48]. Notably, longevity clusters in Sicily are typically found far from major industrial areas and highly polluted zones— such as Palermo, Catania, and the town of Gela and Augusta, which are both associated with large petrochemical complexes [20,49]. Also the Mediterranean temperate climate of Caltabellotta and the *Sicani Mountains*, with temperatures around 20°C year-round, may also be an important longevity-promoting factor, as reported by other studies [9,50].

The influence of green spaces on aging and longevity is also well-documented [51]. Access to natural environments has been associated with slower epigenetic aging [52] as well as an association between forest cover and mental health [53]. The *Sicani Mountains*, with their rich biodiversity and low urban density, offer a liveable setting for reduced allostatic load and increased psychosocial resilience [8].

Another factor that may contribute to longevity in this region is the quality of drinking water [54]. The geology of the *Sicani Mountains*, dominated by Mesozoic limestone formations, results in mineral-rich groundwater containing high levels of calcium (Ca^{2+}) and magnesium (Mg^{2+}) [55]. These minerals contribute to water hardness, which has been inversely associated with cardiovascular disease risk [56]. For instance, in the Sardinia limestone BZ area, water hardness correlates with reduced standardized mortality ratios for coronary artery disease, particularly among men [57]. This protective effect of drinking waters rich in calcium and magnesium against cardiovascular mortality is seen not only in Sardinia but also in other BZs with similar hydrogeological features: for instance, in the Nicoya peninsula, Costa Rica [58].

In the town of Caltabellotta, water hardness has been measured at 35 °F (French degrees), with calcium levels of 79 mg/L and magnesium levels of 38 mg/L [59]. Additionally, the water contains appreciable amounts of bicarbonate, an anion linked to increased lifespan in animal models [60]. While the precise mechanisms remain speculative, it is plausible that the hydrogeological features of the *Sicani Mountains* may play a role in promoting cardiovascular and overall health and longevity [8].

4.3. Lifestyle Factors

Initial observations suggest that the Sicani region shares many prominent characteristics with globally recognized longevity zones: strong social bonds, traditional agrarian lifestyles, and diets based on local, minimally processed foods. Its mountainous landscape, small and cohesive communities, and low exposure to industrial pollutants provide an ideal environment conducive to healthy aging. Residents traditionally follow routines involving locally grown produce, regular physical activity through farming and walking, and supportive family networks that extend across generations [8,61].

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4.3.1. Diet

The Mediterranean diet, which has long been linked to reduced risk of chronic disease and improved longevity, is not simply a health recommendation in the Sicani region but a cultural cornerstone [8,62]. This dietary pattern, characterized by high intake of monounsaturated fats, legumes, vegetables, and whole grains, has been preserved due to longstanding agricultural traditions and socioeconomic conditions that favour simplicity and self-sufficiency.

Some studies have focused on the quality of local olive oil derived from the "*Biancolilla*" cultivar. One study assessed the chemical composition, stability, and sensory attributes of this olive oil over 16 months, indicating that the cultivar and harvest timing significantly influenced the polyphenol content and sensory qualities, such as fruitiness, bitterness, and spiciness [63]. Another investigation focused on their content of bioactive secoiridoids, compounds linked to health benefits [64].

4.3.2. Physical Activity

Moderate physical activity is also recognized as a key factor in preventing early aging and promoting longevity [65,66]. Older people in Caltabellotta remain active, gardening, walking through hilly terrain, and doing chores, naturally incorporating movement into daily routines without formal exercise [8].

4.3.3. Social Factors

A final aspect of interest is the role of psychological and cultural identity. The concept of "place attachment," [67] emphasized in environmental psychology, posits that individuals with a strong emotional connection to their community and surroundings tend to experience better mental health and social cohesion. In towns such as Caltabellotta and Giuliana, residents commonly express a deep-rooted connection to their land, local customs, and religious practices. These psychosocial bonds may serve as buffers against the lifetime stressors that often accompany aging, further supporting the longevity observed in these communities [8]. Eudaimonic well-being, derived from living a life full of meaning and purpose, has been rarely addressed in the BZ literature, with the exception of Sardinia [68]. It seems that some characteristics of the behaviour of the Caltabellotta community, particularly high levels of religiousness, which have been found to be associated with longevity and life satisfaction, echo some aspects detected in the Blue Zone of the other Italian island [69], although the unavailability of adequate controls precludes the possibility of effectively testing this hypothesis. Higher levels of religiousness were also reported in the relative Blue Zone identified in the Netherlands by Deeg et al. [11].

4.4. The Concept of an "Emerging" Blue Zone

Traditionally, BZs have been identified retrospectively as places where a unique convergence of historical, cultural, and environmental factors led to exceptional aging outcomes. However, this concept need not be limited to static or fading enclaves of the past. Instead, BZs may arise from a dynamic interplay between tradition and modernity. Increasing evidence suggests that long-lived communities can emerge, evolve, and eventually decline over time [70]. This temporal dimension is essential: BZs are not fixed points on a map but living ecosystems shaped by the shifting balance between longstanding practices and contemporary influences.

In this view, an "emerging" Blue Zone represents a community entering an ascending phase, in which both longevity and health span markedly improve. This pattern typically emerges when traditional health-promoting practices, such as close-knit social networks, diets rich in local and minimally processed foods, routine physical activity, and a culturally ingrained sense of purpose, persist alongside the gradual integration of beneficial modern factors. These may include access to basic healthcare, improved sanitation, higher education, and moderate technological adoption. Together, these elements foster an optimal health environment where the old and new coexist harmoniously. A plateau phase follows when this balance stabilizes, allowing the community to

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maintain high life expectancy and reduced incidence of chronic, age-related diseases. This balance, as suggested in the case of the Sardinian Blue Zone [70] may be sustained through supportive social norms, local policies, and education systems that preserve both traditional and adaptive modern elements. Yet, this state is delicate, and BZs do not necessarily last forever. The onset of sedentary lifestyles, dietary westernization, increasing psychosocial stress, and other adverse influences can disrupt the equilibrium, leading to a declining phase. This trajectory has been observed in Okinawa and may threaten other known BZs as well [71].

Understanding BZs as dynamic rather than static phenomena provides a more accurate lens through which to interpret longevity in places such as Caltabellotta and, more broadly, the *Sicani Mountains* region. It allows us to study a community in the early stages of emergence, potentially capturing the moment when a population transitions from ordinary health patterns to a period in which a significant portion of its members experience unprecedented longevity. This perspective shifts the focus from mere preservation to active cultivation, suggesting that BZs, once discovered, must also be actively cultivated.

4.5. Strengths and Limitations

A strength of the present study in identifying a potential Blue Zone in Sicily is the use of reliable Italian official population data, as well as the comparison with demographic data from an already certified long-lived area. Nonetheless, by using publicly available population-level data, it is not feasible to trace individual origin and migration events.

5. Conclusions

This article aimed to ascertain whether the regional variation in longevity within Sicily is significant by examining the environmental and lifestyle contexts of longevity in selected *Sicani Mountain* communities. Drawing on a combination of demographic data and extant literature, we explored how local conditions, ranging from diet and daily routines to geography, environment, and social support, contribute to the prevalence of long-lived individuals. Tentatively, superior longevity was found to be associated with living in a small town embedded in a socially agreeable environment, with adherence to an active lifestyle and a Mediterranean diet, where only the advantageous aspects of modernity, such as access to education, improved hygiene, and public healthcare systems, have reached. In doing so, we seek not only to contribute to the scientific exploration of human longevity but also to highlight the value of rural, ecologically integrated lifestyles that may offer insights into sustainable and healthy aging in an increasingly urbanized and globalized world.

Caltabellotta and the nearby *Sicani Mountains* area exhibit key traits of an emerging Blue Zone. While not officially recognized, their alignment with established longevity-promoting factors warrants further interdisciplinary research. These findings underscore the importance of environment and lifestyle in promoting healthy aging and may inform public health strategies beyond the Mediterranean context.

Supplementary Materials: The following supporting information can be downloaded at website of this paper posted on Preprints.org, Table S1: Sicani Mountains villages with the highest 90+/60+ ratio in descending order; Table S2: Comparison of the proportion of ninety-year-olds between Caltabellotta and the Sardinia Blue Zone in the years 1900-1924.

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Abbreviations

The following abbreviations are used in this manuscript:

BZ	Blue Zone
CI	Confidence interval
ISTAT	Italian National Institute of Statistics
KDE	Kernel Density Estimation
SD	Standard Deviation

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