

# Assessment of Potential Territorial Suitability for the Sustainable Production of the “Acquaviva Red Onion” (*Allium Cepa* L.): A Study Using Overlapping Approach



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**Abstract** The onion (*Allium cepa* L.) is one of the most important horticultural crops worldwide; it is widely appreciated by consumers for its nutraceutical effects. In the extreme South of the Murgia area (Apulia, Italy), the Acquaviva red onion has been cultivated for a very long time, as an excellence of this territory. The production of this product typically extends across a rather limited and substantially confined area within the municipality of Acquaviva delle Fonti. Therefore, this circumscribed oasis of production demands territorial planning policies aimed at valorizing its sustainable production by safeguarding the soils most suited to this typicality of production, whose erosion would result in the disappearance of a product with high territorial value. In order to assess the potential territorial suitability for the Acquaviva red onion, data on climate (average temperature and precipitation), soil (texture, pH, electrical conductivity and organic matter content), topography (altitude and slope) and land use were found for each district, through preliminary surveys, and using the Informative Territorial System (SIT Puglia) database. Territorial suitability ranges were established, based on the onion cultivation needs and the indications of the Designation of Municipal Origin (D.E.C.O) production specification and the Slow Food production specification for Acquaviva red onion. Using the GIS software Arcmap Arcgis 10.5, all information layers were overlapped, obtaining the maps of suitability for each feature. Finally, from the overlap of these, it was possible to obtain an overall map of the areas with a greater territorial suitability. The results obtained suggest that accurate territorial planning can be integrated with the contents of a regional development program that is attentive to the valorisation of this typical local product. Beyond the purposes described above, this method could be extended to conterminous territorial areas to verify the possible expansion of the optimal production area.

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## 1 Introduction

Worldwide, the onion (*Allium Cepa* L.) is the second horticultural crop in terms of production and it is widely appreciated for its nutraceutical benefits [1]. Additionally, in Italy, the onion is one of the most important vegetables and it is widespread throughout the national territory with a great number of varieties strongly connected to specific production areas. In fact, every Italian region has numerous typical productions of onion not always recognized by quality certifications. In Apulia there are different varieties distributed in different production areas, such as Barletta's Precocissima White Onion, Margherita di Savoia White, August's Bianca grossa or Agostegna, Rossa and Brown Flat Barletta, and Zapponeta Onion. In particular, in the extreme south of the Murgia area, the Acquaviva Red Onion, cultivated since time immemorial, excels. This local product is known for its organoleptic and healthy qualities and is typically spread in a production area rather limited and exclusively confined to the municipality of Acquaviva delle Fonti, in the province of Bari [2]. It is therefore an oasis of production, which imposes territorial planning policies aimed at safeguarding the soils most suited to the typicality of production, the erosion of which would result in the disappearance of a product with a high territorial value. This risk may be averted by protective and rational choice initiatives concerning alternative land uses. Proper spatial planning can, inter alia, be integrated into the content of a regional development programme that focuses on the valorisation of typical local products. Ultimately, in light of the established symbiotic relation between the produce and its surrounding territory, such endeavors would allow for the implementation of more sustainable production methods. Sometimes, territorial vocation has been studied only with respect to some factors, such as climate characteristics [3]. Recently, the cartographic overlay using GIS based software, allowed to carry out several territorial studies [4–8]. In addition to this, different GIS approaches have been useful to define the territorial vocation for crops, regarding various territorial features, such as soil quality features, climatic characteristics, land topography, and land use [9–11]. This work, therefore, aims at exploring and establishing the productive vocation of the municipal territory of Acquaviva delle Fonti for the red onion produce, identifying areas with different production potential both in terms of quality and in relation to quantitative aspects. Territorial productive vocation consists in the predisposition of a specific territory to host successfully a crop. Vocation, therefore, indicates the efficiency of the symbiotic relationship between a specific crop and the territory that hosts it. The creation of a vocational map aims to differentiate the productive territorial potential by identifying both the areas that allow the optimal development of the crop and those in which such vocations are scarce or even null.

## 2 Materials and Methods

In order to acquire the essential data to characterize the productive peculiarity of the Acquaviva Red Onion, the state of the art was studied through the study of technical-scientific sources, merchandise sources and cartographic sources. In particular, the technical-scientific bibliography concerning the agronomic characteristics of the onion was consulted. Among the different scientific texts and works examined are: “A come Agronomia” [12], “Manuale di Corretta Prassi per la produzione integrata della cipolla” [13] and “Metodi di Valutazione dei suoli e delle terre” [14]. With reference to product sources, the Production Disciplinary of the Acquaviva Red Onion elaborated by the “Consortium for the protection and valorization of the Acquaviva Red Onion” [15], and the Acquaviva Red Onion Integrated Production Disciplinary drawn up by the “Consortium for the promotion, protection and enhancement of the typical qualities of Apulia” [16] have been analysed. These references have been compared with similar elaborations related to other local productions such as the onion of Tropea (Production Specification Onion of Tropea), and that of Margherita di Savoia (Production Specification for Margherita di Savoia onion PGI).

The cartographic elaborations have required the acquisition of a chart able to represent the toponymy and agronomic inter-communal subdivision in order to more effectively correlate the analyses and the results to the same territory. The chart was built starting from the framework of cadastral union to which the subdivision of territorial districts (contrade) was superimposed (Fig. 1). This choice is justified by the possibility of correlating analyses and subsequent vocational attributions to territorial units (districts) easily identifiable by place names and agronomic characteristics. In fact, the districts allow easy-to-interpret correlations between the geography of the territory and its production variability. For the analysis of the territorial characteristics deemed essential for the study, official cartographic sources have also been used, such as the site of the Territorial Information System (SIT Puglia). The cartographic elaborations have been conducted in GIS environment through the use of the software Arcgis Arcmap 10.5.

The study has been articulated in several phases, synthetically represented in Fig. 2. Analysis of the sources above-mentioned allows to identify the indices qualifying the production performance of the Cipolla Rossa di Acquaviva in the area under analysis and the corresponding quality classes. Figure 3 indicates three classes of production capacity (i.e., high, medium, low) defined through value ranges attributed to various production indices, further grouped into the commercial, organoleptic, and field performance category.

Additionally, territorial factors that influence the production capacity of the onion in the same territory were identified and subsequently reported on the cartographic base (see Fig. 1). The spatial reference framework featuring such factors was developed by, firstly, adopting the altimetry map and the land use map from SIT Puglia.

Secondly, additional qualifying factors consisting in soil maps (texture, pH, electrical conductivity and soil organic matter) and maps of average temperatures and

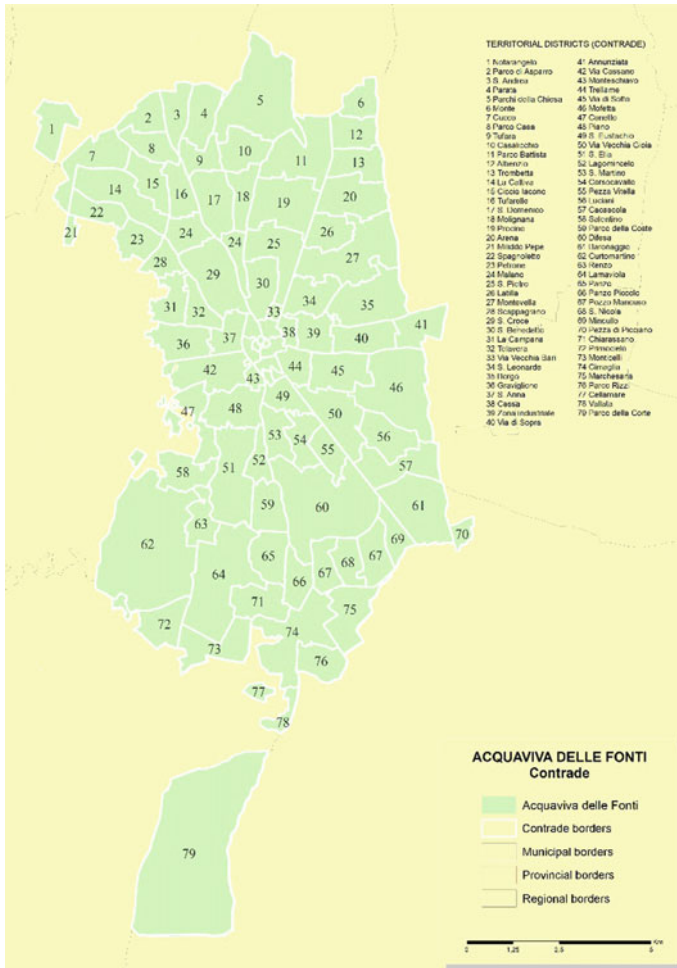
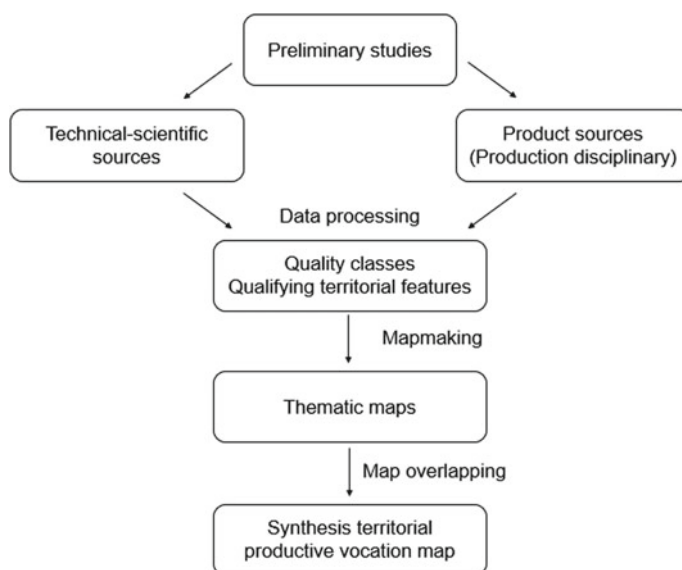


Fig. 1 Chart of Acquaviva delle Fonti with the territorial districts subdivision (contrade)

precipitation were developed through analyzing data from soil analysis and the Civil Protection Service of the Apulia Region respectively. Such thematic maps were then subsumed under the three classes of productive vocation: high, medium and low (Table 1), ultimately producing the maps of territorial vocation. In other words, from the maps it is possible to read, for each territorial factor considered qualifying, the level of territorial productive vocation of each district for the cultivation of the red onion of Acquaviva delle Fonti. Furthermore, the areas with different vocations are represented by different colors: in green are reported the districts particularly suited for the cultivation of onion, in yellow the medium-suited areas and in red the areas not suitable for the cultivation of the product. Finally, the cartographic overlay of



**Fig. 2** Study phases scheme

the thematic maps so produced has allowed to obtain a synthesis of the productive vocation of the onion of Acquaviva across the territory (Fig. 4).

The identification of production indices and territorial qualifying factors carried out according to the cultivation needs found in the literature and the indications of the production specification of the onion of Acquaviva and the specification Slow Food, has made it possible to differentiate the territorial quantitative–qualitative profile of the onion in the Acquaviva delle Fonti countryside by identifying three ranges of territorial vocationality as per Table 1. With regard to the selection of the territorial qualifying factors, those considered most significant for the determination of the quantitative–qualitative aspects of the product were identified, and listed below: average temperature and precipitation (climatic factors); texture, pH, electrical conductivity, soil organic matter (pedological factors); altimetry (topographical factors); land use.

In relation to climatic factors, the annual average values of temperatures and rainfall have been taken into account. The lack of official thermo-pluviometric stations within the area under study, led to the use of other databases, namely those provided by the Civil Protection Service of the Apulia Region and the website [www.climate-data.org](http://www.climate-data.org). Both provide data for the entire municipal area without any internal differentiation. The climate data were thus processed through a comparison between the two sources used, referring to the period corresponding to the crop cycle of the onion (December to June). In the knowledge that pedological factors are decisive for the productive results of quality, it was considered necessary to evaluate the variability of the nature of the soil within the municipality. In the absence of official sources, a survey has been conducted to take the results of physical–chemical analysis of the

QUANTITATIVE INDICES			
Bulb weight (g)	300	300 – 600	> 600
Bulb diameter (cm)	< 10	10-12	> 12
Average yield (q/ha)	80-100	100-150	150-200
Harvest period	EARLY	MEDIUM	LATE
QUALITATIVE INDICES			
Bulb form	SFERIC BULB	FLAT BULB	
Bulb color	SCARLET RED	PURPLE RED	COPPERY RED
Flesh color	PINKYSH RED	WHITISH	PURE WHITE
Sweetness	SWEET	SWEETISH (SPICY AFTERTASTE)	
Smell (back-nasal way perception)	AROMATIC		SOFT SMELL
Flesh consistency	SOFT	COMPACT	CRUNCHY
Size uniformity	NON UNIFORM	UNIFORM	

- high production capacity	➔	<ul style="list-style-type: none"> <li>- bulb weight: 300 g</li> <li>- bulb diameter: 10-12 cm</li> <li>- average yield q/ha: 150-200</li> <li>- early harvest</li> <li>- flat bulb</li> <li>- purple red bulb, sweet and uniform</li> <li>- soft and pinkysh red flesh</li> <li>- aromatic smell</li> </ul>
- medium production capacity	➔	<ul style="list-style-type: none"> <li>- bulb weight: 300-600 g</li> <li>- bulb diameter: &lt; 10 cm</li> <li>- average yield q/ha: 100-150</li> <li>- medium harvest</li> <li>- sferic bulb</li> <li>- scarlet red bulb, sweetish and non uniform</li> <li>- crunchy and whitish flesh</li> <li>- soft smell</li> </ul>
- low production capacity	➔	<ul style="list-style-type: none"> <li>- bulb weight: &gt; 600 g</li> <li>- bulb diameter: &gt; 12 cm</li> <li>- average yield q/ha: 80-100</li> <li>- late harvest</li> <li>- sferic bulb</li> <li>- coppery red bulb, sweetish and non uniform</li> <li>- crunchy and pure white flesh</li> <li>- soft smell</li> </ul>

**Fig. 3** Classes of production capacity defined through value ranges attributed to various production indices

land carried out during the two-year period 2019–2020 by local laboratories commissioned by farms. The collection of analysis certifications was carried out in order to cover the entire territory as well as the individual districts, with a significant number of analytical results. The characteristics taken into consideration concern the soil texture and structure, the total organic matter content and the depth of the soil depth. Among the various factors that determine the topography of a territory, altimetry is undoubtedly the characteristic that influences the productive performance of crops because it helps to determine climatic conditions with particular reference to temperature. In order to design the map of the productive vocation of the onion connected to the altimetries, the relative excerpts of information from the SIT Puglia have been

**Table 1** Territorial features ranges of vocationality

Territorial features	High vocationality	Medium vocationality	Low vocationality
<i>Climatic features</i>			
- average temperature (°C)	15–25	10–14	<10/>25
- precipitations (mm/year)	400–700	700–800	<400/>800
<i>Pedological features</i>			
- texture	Loamy Sandy loam	Clay loam Clay sandy loam Clay silty loam	Others
- pH	6,5–7,4	7,5–8,5	<6,5/>8,5
- ECe (mS/cm)	<1,2	1,2–1,8	>1,8
- SO (%)	>1,0	0,5–1,0	<0,5
<i>Topographical features</i>			
- altitude (mamsl)	<300	300–400	>400
<i>Land use features</i>			
- consociation	>3	2–3	<2

acquired, subdividing, with appropriate elaborations, the territory in three altimetric bands. The use of soil was considered a useful indicator in assessing the productive potential of the red onion of Acquaviva through the agronomic productive correlations between the prevailing crops and the cultivation of onion in a given area. Also, for this character the cartographic source of the informative system of the SIT Puglia has been used.

### 3 Results and Discussion

The production of the map of the districts, used as a base map for the analyses and territorial elaborations carried out, is the first result of this study. It is a map that includes about 13,000 ha of municipal territory, divided into districts on a cadastral basis (framework of union). It displays location of districts with the corresponding sheets of map and extension (ha). From the cartographic elaboration (overlapping of the contradas to the sheets of map) they have been perimeter 79 contrade (Fig. 1). The territorial significance of the districts, already expressed above (method) is confirmed by the mean surface area of 163 ha per unit.

As reported by Grassano et al. (2011) the territory evaluation for a special production is determined by investigating the agents related to soil properties, climate, topography factors and by local expert opinions [17]. The map of territorial vocationality related to the average temperature in reference to the cultivation cycle of the onion highlights only two bands of the three possible ranges, and these are the

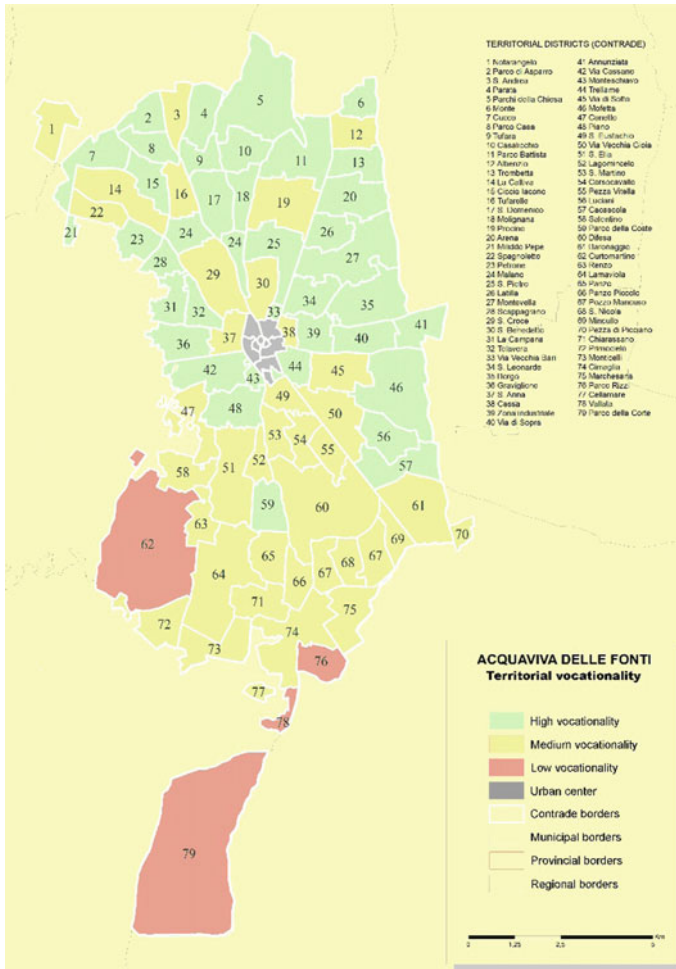


Fig. 4 Territorial vocationality synthesis map

high and medium level. With reference to the thematic map related to average rainfall, defined in relation to the production period of the onion, homogeneity was found, as the whole territory is characterized by the only class with high vocationality (400–700 mm/year). It is, therefore, a map that, in the inter-map overlapping process (Fig. 4), will not have an impact on the territorial differentiation of productive vocationality.

The thematic maps relating to pedological aspects (texture, pH, electrical conductivity and soil organic matter) show greater territorial differentiation [18]. As for the soil texture, 25 districts (32% of the municipal territory) fall into the high-vocationality range, 52 districts (66% of the municipal territory) in medium vocationality and only 2 districts (Cimaglia and Marchesana) have a low vocationality. The



latter are located at the extreme south of the countryside of Acquaviva delle Fonti, while those falling in the middle belt occupy the central north–south axis of the municipal territory. In the map of territorial vocationality linked to pH it is possible instead to identify the East–West transversal bands with different vocations. Altogether 43 districts (54% of the territorial surface) show a high vocationality, while the remaining districts have an medium vocationality (35 districts); the exception is the district Cessa where there was a low territorial vocationality. The thematic chart of electrical conductivity, shows a lower variability in vocations, as 75% of the territory presents itself to medium vocationality. The other two classes are present with different percentages (16% of the territory to high vocationality and 9% to low), specifying that the areas to high vocationality are concentrated in the south-east portion of the communal territory. With reference to the content of soil organic matter, the territory of Acquaviva delle Fonti shows good levels that define only two categories of vocationality: high vocationality (content of organic matter > 1.0%) affecting 45 districts (57% of the communal territory) and medium that defines 34 districts (43% of the territorial surface). The analysis of altimetry has made it possible to draw up a thematic chart of vocationality that divides the territory into three transversal bands. The territory to the north is defined by a high vocationality (55% of the communal territory); the central portion is defined by an medium value of vocationality and interests approximately 33% of the territory; finally, the third band that constitutes the less extended portion is relegated to the extreme south. Finally, considering the territorial thematic map related to land use, it has been shown that a large part of the territory has medium values of vocationality (68% of agro-municipal) and is associated mainly with tree crops. While high vocationality has been recorded in the districts where differentiated agronomic uses prevail, low vocationality was found in areas presenting a narrowed range of cultivations, such as olive groves and arable land. The synthesis map (Fig. 4) demonstrates that a large part of the territory (95%) shows a vocation for the production of red onion between medium and high values. More specifically, the northern portion of the agro (50% of the land area) has a high productive vocation. All the results obtained are not comparable to previous studies, because in literature there are not similar analysis about the study area and the red onion crop.

## 4 Conclusions

This study confirmed the vocationality of the territory of Acquaviva delle Fonti for the production of red onion, verifying a diversification of the same within the municipal territory. The zoning obtained showed that the productive potential of the red onion is still poorly exploited because only a small part of the territory manifesting high productive vocation, is in fact used. Notably, the degree of under-utilization increases particularly in areas with medium vocations. These considerations call for territorial development policies aimed at enhancing the product by increasing the areas involved. It also seems essential to launch agronomic programming of

farm production in order to make the best use of the ability to adapt the onion and its versatility to be used as an intermediate crop while overcoming the limitations linked to the necessary crop rotation. Finally, the authors recognize that the method developed can be used, through appropriate corrections, to evaluate the productive vocationality of other territories in relation to agricultural products similar to the Red Onion of Acquaviva delle Fonti.

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