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Research Article

An automated classification system for urban areas matching the 'city country fingers' pattern: the cases of Kamakura (Japan) and Acireale (Italy) cities

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Abstract

The uncontrolled expansion of urban areas is one of the main factors that reduce the liveability of cities. In recent years, to contrast urban sprawl, several nations have promoted policies aimed at developing urban green spaces. The importance of green oases within cities had already been highlighted, in 1977, by the architect Christopher Alexander who had developed a series of patterns including 'City Country Fingers' claiming that city development should consider the prolongation of country land in to the urban area.

In several cities, especially in Japan, it is possible to recognize the imprint of urban development based on country fingers. This term refers to extensive urban intersections of agricultural land or wooded hills which, from the peripheral areas, penetrate the city. Inside them, there are urban windows, called city fingers, whose development direction is opposite to those of the country fingers. To recognize and analyze, in an automated way, these particular structures, a Python-based application was created. Starting from the original high-resolution image of Google Earth, a complete analysis was performed, labeling and delimiting urban and vegetational areas and extrapolating the main geometric parameters of the country and city fingers. The finalization of the results obtained was carried out through a classification model whose criteria were based on Alexander's pattern.

Thanks to this classification scheme, the distinction between Active Green Areas (country fingers) and Passive Green Areas (gardens and public parks) have been revealed for the analyzed cities. The tests performed showed almost ideal conditions for the city of Kamakura and a limited match for the urban area of Acireale. The proposed method is suitable for fields of application that require a qualitative and quantitative determination of the vegetation cover present within the city, an essential condition for correct territorial planning.

Key words: city fingers, country fingers, Alexander pattern

Introduction

The irregular and uncontrolled expansion of urbanized areas, defined as urban sprawl (Johnson 2001; Nechyba and Walsh 2004; Patacchini et al. 2009; Habibi and Asadi 2011; Karakayaci 2016), is one of the main environmental challenges that have significant impacts on the quality of life and economic performance of cities. As a result, there is an abandonment of agricultural activities and urban sprawl into agricultural land, sometimes of high quality (Dupras and Alam 2015; Dupras et al. 2016). In contrast to this common trend, several cities around the world have promoted different policies to manage the growth of urban areas and protect natural and agricultural areas (Taylor et al. 1995; Bengston et al. 2004). An example is the USA, where green regulation has become a fundamental factor for the management of urban spaces, involving both public and private ownership (Cooper 1996; Houde 1997).

The importance of urban green has been associated with the development of multiple advantages in the environmental field: aesthetic–ornamental function, regulation of the microclimate and expression of productivity (Bajo and Di Noi 2005); influence on local air quality both directly and indirectly by altering the surrounding atmosphere and conditioning of local weather (Nowak 1995; Nowak et al. 1998); reduction of the emission of Volatile Organic Compounds (VOC), which favors the development of O_3 and CO, related to the increase in vegetation cover (Cardelino and Chameides 1990).

Even in the social field, urban green plays a fundamental role under various aspects: green areas contribute to the quality of life in the city (Bonaiuto et al. 2003; Chiesura 2004); the social, cultural and aesthetic functions offered by the open city spaces allow socialization, recreation and leisure in the open air (Tyrvainen et al. 2005); the desire of citizens to escape from pollution, traffic and cement can be seen from the concentration of people in green spaces (Mirabile 2004); open spaces favor social interactions between people, environmental education for children and promote a compatible relationship between humans and nature and consequently creating urban sustainability (Cengiz et al. 2018).

In addition to social, economic, cultural and environmental functions, ecosystems spontaneously produce goods and services to society (De Groot 1992; Bingham 1995; Costanza et al. 1997a; Daily 1997; Bolund and Hunhammar, 1999), defined, according to the theory developed through the contribution of ecologists, sociologists and economists, as 'a flow of matter, energy and information from natural capital stocks that produces benefits for humans' (Costanza et al. 1997b).

Extensive integration of green spaces within urban areas therefore has significant advantages, making life within cities more pleasant. These concepts were adopted by the architect Christopher Alexander who, in 1977, introduced 253 empirical design rules and solutions, called 'patterns', to suggest guidelines for creating good design practices. Within these patterns, some of them may be chosen for the simple implementation of a project (Park 2015). Subsequently, the pattern language has often been adopted by designers, builders and others to pursue urban development by following these proven models and considering the whole context surrounding their project (Wheeler 2013).

Following the concepts reported in the 'Pattern Language' book (Alexander et al. 1977), the application of patterns in the context of sharing green spaces within cities can be found on important themes including 'Agricultural Valleys', 'City Country Fingers', 'Scattered Work (places)', 'Density Rings' and a 'Web of Public Transportation' (Alexander et al. 1977; Harrison and Coplien 2001; Gabriel and Quillien 2019).

We believe that an approach based on the 'City Country Fingers' pattern is relevant for urban development and ecology, for a number of reasons. In the classic urban planning approach, the quantification and distribution of green areas within the territory are aimed at guaranteeing an acceptable degree of livability of the resident population, based on the satisfaction of some factors (World Health Organisation 2016). The adopted pattern, based on the penetration of the countryside within the cities, allows a direct connection between agricultural land and urban spaces with undoubted benefits: (i) all city-dwellers would be within a 10-min walk of both the countryside; (ii) it would allow people easy access to nature, and a more significant nature than underused yards and parks; (iii) agricultural commodities, meat and animal derivatives, produced on farms located in the countryside, could be a genuine alternative to imported products; and (iv) urban fingers would completely replace low-density suburbs (Orr 2015).

Therefore, in this case, not only there is an adequate percentage of green spaces within the city, but their characteristics make them actively liveable by citizens. Defining urban green in terms of active or passive use of citizens is an element not considered in the evaluation of the sustainable development of the territory, but certainly a fundamental criterion for improving the quality of life in cities.

For all this series of reasons, urban areas that have a high correspondence to the pattern can be considered to have an added value compared to cities characterized by high amounts of greenery, but not actively usable.

To classify the urban areas, it is therefore necessary, in addition to a classification model based on Alexander's pattern, to have a tool that can recognize what cities (or parts of a city) match with it. In the digital age, such a tool can only be an application capable, not only of recognizing country and city fingers, but also of evaluating the occupied surface and their width and length.

The versatility of the application should also allow the automation of various GIS operations such as those necessary for the quantification and distribution of urban green areas, necessary for the zoning plan (Cetin 2015). These activities are generally carried out by specific GIS applications that assist users in tracing boundaries and in calculating lengths and areas, using manual tools. However, the main limitation in the use of these techniques concerns the analysis of irregularly shaped areas. For them, tracing outlines that overlap the original ones is quite difficult, imprecise and time-consuming.

The aim of the work, which concerns the creation of an application capable of classifying urban areas according to the 'City Country Fingers' pattern, passes through the achievement of four main objectives:

i. creating a classification scheme based on the aforementioned Alexander's pattern;
ii. implementing a Python-based software system capable of identifying country and city fingers within the urban center;
iii. delimiting, in a precise way, the urban areas from the green spaces and calculating the main geometric parameters (surfaces and linear dimensions), in order to establish the level of conformance to the pattern, according to the previous classification scheme.
iv. implementing a series of queries which, on the basis of the previously evaluated parameters, allow us to extract significant data while removing irrelevant factors (noise) from the image.

The latter two functions could be useful within other activities that require the use of GIS (thematic maps in the field of Earth Science, Civil Protection and Emergency Management, Safeguarding of Cultural Heritage, etc.). On the contrary, the absence of automated procedures for carrying out the aforementioned operations can lead, in some cases, to results that differ from the real ones. The products obtained with freehand tools are strongly affected by the subjectivity of the operator and make it difficult to quickly reach an adequate level of precision.

Moreover, the ability to perform queries allows us to extract important data on the territory under study such as, e.g.

determining the country or city fingers with a greater surface or length, calculating the distance of a country finger from the city center, eliminating the disturbance produced by small green areas, and so on.

Automating the procedure to make it independent of the operator's subjectivity, and implement queries capable of extracting information from the context, is a further objective that we propose, preparatory to achieving the main purpose of the work.

The Christopher Alexander's pattern language

Maintaining a balance between urban territory and countryside, within towns and cities, allows you to control the continuous expansion of urbanization that makes life in the city unbearable. A team of scientists led by Christopher Alexander, in 1977, developed a series of patterns including '*City Country Fingers*', which involves the development of extensive prolongation of country land to the center of the city. As can be seen in Fig. 1, this pattern provides some recommendations regarding the size of urban and country areas and the distance between them. The urban fingers should never be more than 1 mile wide, while the farmland fingers should never be less than 1 mile wide.

The maximum city finger width value is calculated taking into account each inhabitant should be no more than 10 min walk from the countryside. Each country finger should not be <1 mile wide, which corresponds to the minimum acceptable size for typical farms.

To implement such a system, policies are needed to support the creation of 'country oases' within cities, which can be achieved through a series of measures: (i) by developing policies that encourage the reconstruction of small farms that can adapt to large swaths of countryside one mile; (ii) preventing cities from expanding irrationally in all directions (urban sprawl); (iii) making the countryside accessible to all, favoring contact of people also with the countryside cultivated by private individuals.

In this context, agricultural valleys are considered land to be protected from any development that could irreversibly alter the fertility of the soil, which is unique in its kind. The '*Agricultural Valleys*' pattern considers preserving these areas by allocating them to farms, parks or, in the case of temporary non-use, to keep them as wilderness areas. Consequently, the development of cities must be diverted to the hills and plateaus, allocating the valleys to agriculture.

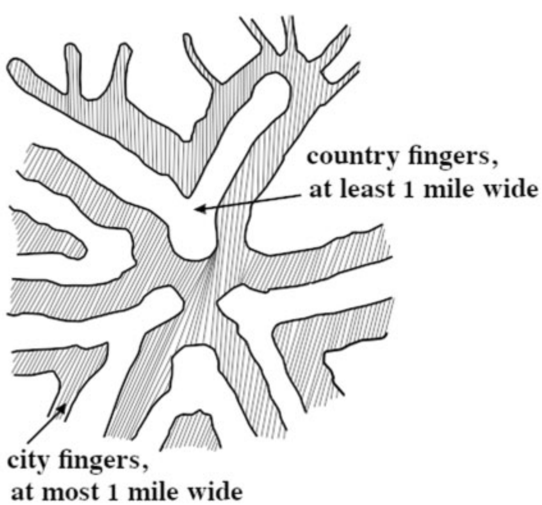

Figure 1: City country fingers pattern. By Alexander et al. 1977 (redrawn)

These two important patterns concerning the location and development of urban and rural areas within them are associated with additional patterns that contribute to determining their success. We refer to the pattern 'The distribution of towns', which emphasizes the importance of a correct distribution of the population: an excessive concentration in space that places an enormous burden on the general ecosystem of the region and a series of problems that damage the livability of the urban area. As large cities grow, there is a worsening of the quality of life due to the increase in air pollution, insufficient transport, shortage of water and housing, difficulties in the waste disposal and density of life constrained within increasingly more limited spaces. The result will be an ecology projected toward an inevitable crack. The impact of the population on the ecology of the environment can be reduced by preventing the population from growing to excess, by providing for a rational distribution within urban areas.

Study area

Our study area concerns the city of Kamakura, in Japan, and the urban area of Acireale, an Italian town.

Kamakura is a city in Kanagawa prefecture that belongs to the Kantō region, on the island of Honshu. It extends for 39.67 km^2 of total area, divided into the urban areas of *Kamakura, Koshigoe, Fukasawa, Ofuna* and *Tamanawa*.

The city is enclosed on three sides by hills, while the fourth opens onto Sagami Bay, a beach of fine sand. The population, according to data reported by the United Nations Organization in 2015, is 173 019 inhabitants.

Acireale is an Italian town in the metropolitan city of Catania, in Sicily, of 51 899 inhabitants, which unites the municipalities of *Aci Catena, Aci Sant'Antonio, Aci Castello, Aci Bonaccorsi, Valverde* and part of *Santa Venerina and Zafferana*, with a total population of 130 000 inhabitants. The Municipality of Acireale, developed on the southern slopes of the Etna volcano, extends for 40.43 km^2 and includes in its territory some picturesque seaside villages with tourist ports like Santa Maria la Scala and Capo Mulini.

In Figs. 2a and b, the centers of the two cities and the administrative limits in which their territory is included.

Methods

The work that led to the classification of the urban areas of Kamakura and Acireale, according to Christopher Alexander's 'City Country Fingers' model, was based on two distinct but complementary approaches. The first consists in the analysis of the 'City Country Fingers' pattern to define a classification scheme and establish the level of adherence of cities, to highlight the presence of Active Green Areas (AGA). The second is based on the implementation of a Python application capable of recognizing country and city fingers, calculating the main geometric parameters and performing queries to extract meaningful information and eliminate Passive Green Areas (PGA).

The initial activity was therefore focused on defining a classification scheme, based on Alexander's pattern and divided into four levels of adherence: high, medium, low and absent. The classification Level 1 (high adherence) concerns urban centers having a high component of vegetation cover that penetrates the urban center with the maximum width of the country fingers which must be at least 1 mile. These extensions must

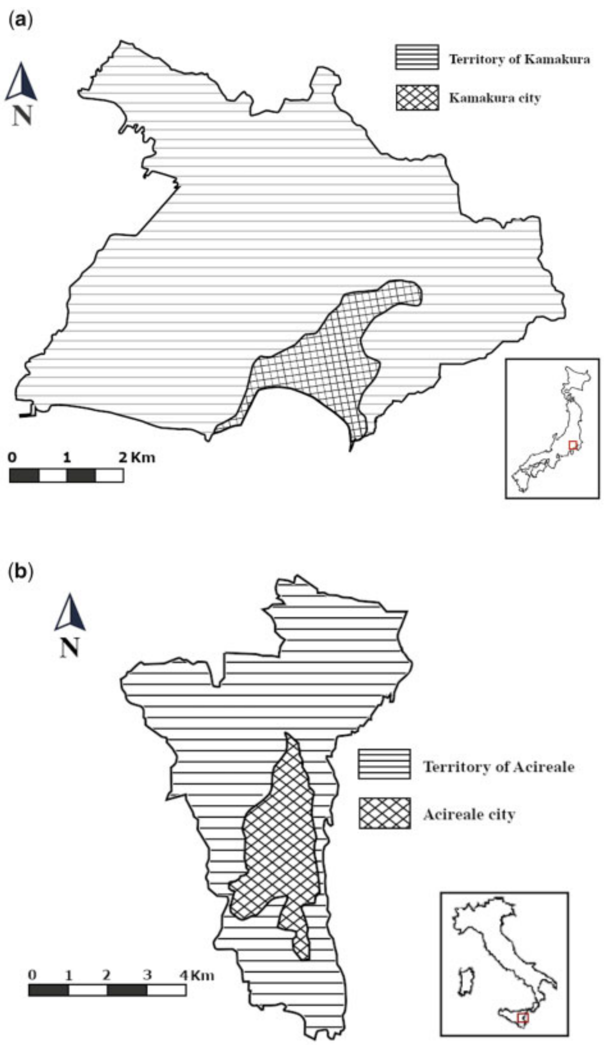

Figure 2: Territory and city center of Kamakura (a) and Acireale (b)

develop from all cardinal points and the maximum width of the corresponding city fingers must not exceed 1 mile. The countryside areas must be reachable from every point of the city by covering a distance not exceeding 1 mile, i.e. be reachable within no more than 10 min on foot. A high level of adherence is achieved when all four requirements are met.

For the classification in the medium and low categories, the criteria to be verified are less stringent and it is necessary that, respectively, at least three or two of them are satisfied. The urban centers that fall into Level 4 are characterized by the absence of intersections between urban centers and rural areas and in which, therefore, none of the four criteria is met.

The criteria used for the classification of urban areas according to the 'City Country Fingers' design pattern were focused on two different methods. The first of them concerns the high-level classification, based on the ideal characteristics described by Alexander in the book 'A Pattern Language: Towns, Buildings, Construction' and shown in Fig. 1.

An experimental approach was adopted to establish the other two classification levels, based on the observation of different urban centers in Japan, a country in which the pattern in question is widely used. By using Google Earth measuring tools, it was possible to calculate the width of the country and city fingers and their distribution concerning the four cardinal points. The criteria for the definition of the medium and low adherence levels therefore arose from the situations that most frequently occurred in the cities analyzed. At the opposite extreme, compared with the model proposed by Alexander, Level 4 (absent adherence) is attributed to urban centers where none of the four parameters is verified.

Once the classification scheme was completed, the application was implemented that made it possible to automate the steps necessary to achieve the final result, that is, to attribute the level of adherence to the cities of Kamakura and Acireale.

The first activity was to download the images, through Google Earth, of the urban centers related to the two areas analyzed, acquired at the maximum resolution available (4800 $\times$ 2823 pixels). This solution was deliberately used instead of the classic Landsat and/or Sentinel satellite images which, supported by GIS applications, would have facilitated the data analysis process. The choice of using a pure image processing approach, based solely on the Pillow and OpenCV2 libraries of the Python programming language, has allowed us to implement complex techniques on classic RGB images.

Before processing the high-resolution image, several tests were performed on a portion of the original image of 500 $\times$ 300 pixels in size, referred to some proximal country fingers to the center of Kamakura. This choice was made both to simplify the analysis and display of the results, and to reduce the execution time required for scanning the image pixels.

The program implementation was carried out by means Pillow and OpenCV2 libraries of the Python programming language. These APIs allow you to extract the RGB values of each pixel and carry out a series of operations aimed at labeling the vegetation cover and urban areas by tracing their limits and identifying the city and country fingers. After tracing the boundaries, the interlocking pattern between country and city fingers has been identified according to the following procedure.

Through a mobile square window of 400 pixels per side (1000 $\times$ 1000 m), the pixels present were sampled, storing their values in the variables green_area and urban_area. During the tile movement from the peripheral areas to the lower ones of the image, the vegetative density and the urban density (ratio between green_area or urban_area and total window area) were calculated (Spina and Tramontana 2021). A fundamental assumption is that in the peripheral areas, mainly consisting of country areas or woods, the vegetative density is around 100% (or $>$ 90%). On the contrary, in urban areas, the vegetative density will vary between very low values (between 0% and 10%). In the situation described in Fig. 5a, the transition between these two extreme values will occur abruptly with a single tile, whose density values will express significant intersections between the two areas. On the contrary, values that denote comparable percentages between urban surfaces and green areas, calculated in at least two sampling windows, will be typical of the situation of Fig. 5b. The choice of window size was made in consideration of the maximum values of the city fingers, foreseen by the Alexander classification. These values will prevent the window from falling entirely within the urban area of the city fingers, mistakenly believing that it has reached the city center.

To identify country and city fingers, along the E–W and N–S sides of the image, the scan was performed, respectively, on horizontal and vertical lines.

Obviously, a high or reduced number of movable tiles in the passage between peripheral green areas and urban areas will indicate the lesser or greater development of the country and city fingers of the specific urban center. In this phase, the vegetative and urban density and the coordinates of the corresponding

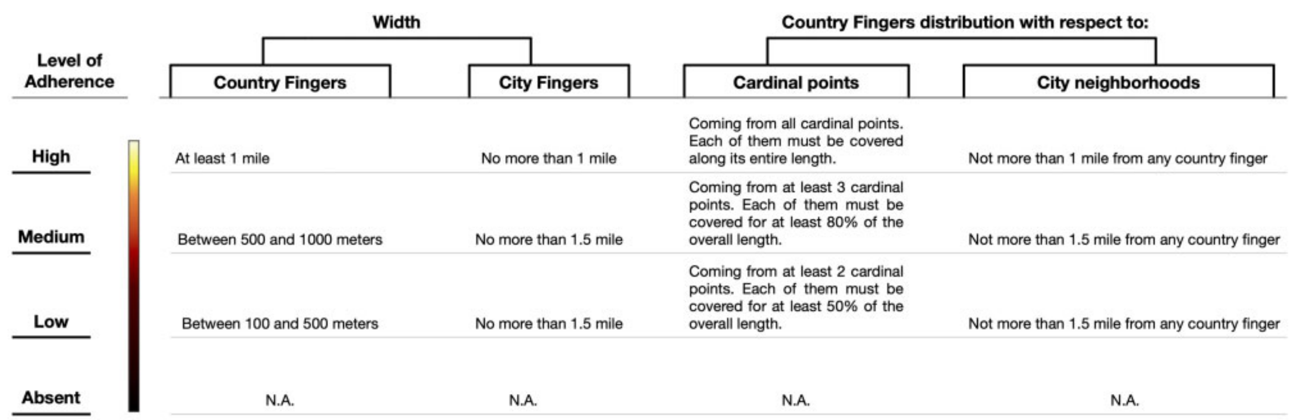

Figure 3: The classification scheme for the ‘City Country Finger’ pattern

mobile window (upper left vertex and lower right vertex of the square) were inserted in a JSON file. During the second scan, the density mapping of each square within the image was performed, considering those in which significant density contrasts were present, belonging to possible country or city fingers. The use of a specific algorithm made it possible to reconstruct the boundaries between urban and green areas and close them in order to isolate the corresponding country or city fingers. At this point, the area, length and width of each finger were also calculated. After the execution of the procedure, whose description we have simplified, it was also possible to define the distribution of both fingers with respect to the four cardinal points, as indicated in the diagram in Fig. 3.

At the end of the elaboration process, to verify the adherence of the two urban areas to the ‘City Country Fingers’ pattern, the classification model with four levels, indicated in the scheme in Fig. 3, was used.

Results

The processing of the two images produced a series of results that made it possible to obtain a final image without noise and to calculate the parameters necessary to define whether the reference sites are in agreement or not with the ‘City Country Fingers’ pattern. In our case, the noise was represented by small gardens or public parks (PGA), present within the city, not considered significant for our analysis and therefore entirely removed.

Figure 4 shows the results, at a graphic level, obtained at the end of the processing: on the left, the original image and, in the center, the one obtained after processing for the urban center of Acireale. The results indicate four country fingers located to the South and North of the urban area, indicated respectively with A–B and D–E and a modest country finger (C) which, from the West, penetrates the city. In the other sectors, the vegetation surrounds the city, showing no appreciable intersections with it.

Table 1 shows the length and width values for each country finger relating to the two cities analyzed. It should be noted that in the city of Acireale, the country fingers have a width interval between 350 and 865 m, coming from three cardinal points (North, South and West) and the prevailing direction of development, corresponding to the axis of the country finger, is N–S. From every part of the city, it is possible to reach at least one country finger by covering distances not exceeding 1 mile. The city fingers, shown in Table 2, have a width between 295 and 440 m, while the length can even reach 1 km.

The visual analysis of the city of Kamakura (Fig. 4), shows a greater vegetative density and a substantial part of the vegetation cover penetrates inside the urban center, covering all cardinal points except for the marine part to the south. The image on the far left at the bottom shows many and well-developed country and city fingers with a maximum width in the first case of about 1 km and the second case of 542 m. Furthermore, the path to reach at least one country finger is $<$ 1 km from any point in the city.

Discussion

Before discussing the results obtained at the end of the Python-based software processing, we focus on two topics that explain the reasons for the choice and the criteria followed for the creation of the classification model based on the ‘City Country Fingers’ pattern.

The choice of the classification model seems to be the most appropriate to distinguish between the PGA and AGA within the urban center. A qualitative approach based on the use of green areas in an active or passive way refers to the possibility of carrying out (or not) services and/or productive activities within them. The passive use of urban greenery, located mainly in parks and public gardens, concerns the classic approach based on the possibility of enjoying the countless benefits provided by vegetation: air healthiness, improvement of the aesthetic factor, lowering of stress levels and increase of well-being, curative help for those suffering from depressive illnesses, etc. In contrast, using green areas actively means tapping into their potential, by creating activities that can enhance their agricultural, landscape and wildlife aspects. The development of farms in country fingers makes it possible to obtain vegetables and fruit directly taken from the fields and not bought in the large city markets, where the origin cannot be directly ascertained. The same goes for animal breeding (cattle, sheep, pigs, etc.) and the corresponding derivative products (meat, milk, butter, etc.). Additional activities and services could be represented by hunting, the development of agritourism, the creation of trekking routes, and so on. In this case, the prerequisite is the existence of country fingers consisting of mountains and/or wooded hills, as in the case of the Kamakura area.

The fundamental point of our discussion concerns the possibility of differentiating the two types of urban green by giving greater weight to vegetation capable of being actively exploited

Figure 4: The results of the image processing of the Acireale and Kamakura cities. In the figures on the left the original image, in the central ones the result after the processing phase and in the figures on the right of the country and city fingers for both places indicated by letters and numbers. The vegetation is shown in green and the urban center in transparent gray

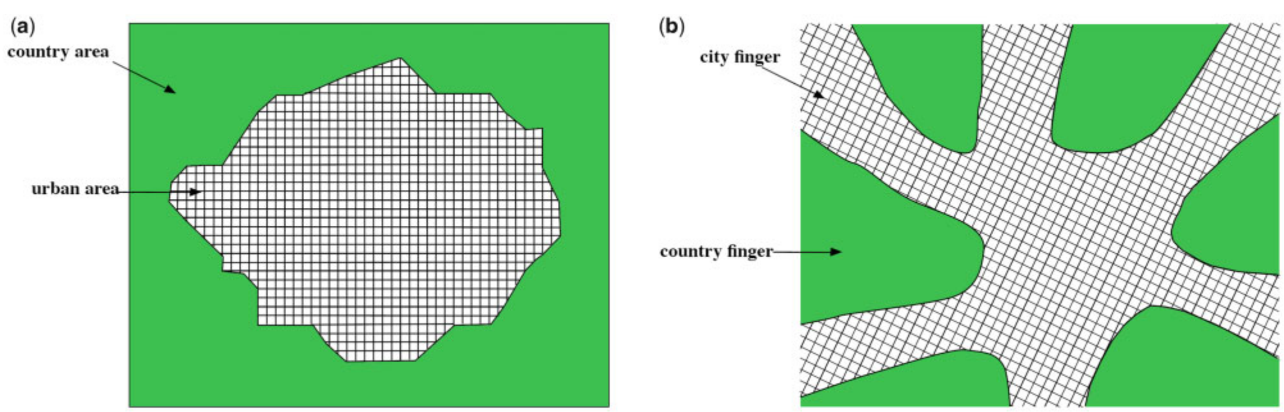

Figure 5: Two examples of classification of urban areas relating to the 'City Country Fingers' pattern. In case (a), there is no adherence to the pattern: the agricultural lands surround the city and have no intersections with it. In (b), there is maximum adherence to the pattern (ideal case): fingers of the countryside branch off from all four cardinal points and penetrate the inner city

than that used passively for recreational or regenerative purposes by citizens. Cities made up of AGA have different potentials from others that do not have them, as they are potentially able to create a series of economic and productive activities that would give ample benefits to the inhabitants of the urban center.

Table 1: Geometric parameters and geographical position of the country fingers, listed in Fig. 4 and related to the cities of Acireale and Kamakura

City	Country fingers	Width (m)	Length (m)	Position	Direction
Acireale	A	680	887	South	N–S
	B	865	1066	South	N–S
	C	350	900	West	E–W
	D	585	1430	North	N–S
	E	405	1212	North	N–S
Kamakura	F	634	1275	West	NE–SW
	G	870	520	West	N–S
	H	510	870	West	N–S
	I	565	460	North	N–S
	L	380	940	North	N–S
	M	280	660	North	N–S
	N	276	345	North	NE–SW
	O	280	380	North	E–W
	P	1014	950	East	E–W
	Q	500	490	East	E–W
	R	452	580	East	NE–SW

Table 2: Geometric parameters and geographical position of the city fingers, listed in Fig. 4 and related to the cities of Acireale and Kamakura

City	City fingers	Width (m)	Length (m)	Position	Direction
Acireale	1	440	1130	South	NNE–SSW
	2	535	650	West	NE–SW
	3	295	507	North	N–S
Kamakura	4	293	990	West	NNE–SSW
	5	424	1040	West	N–S
	6	436	872	West	N–S
	7	190	331	North	N–S
	8	105	656	North	N–S
	9	410	1050	East	NE–SW
	10	542	484	East	E–W
	11	254	336	East	NE–SW

Another important aspect concerns the criterion chosen, in both territories, of unrelating the model adopted from that of agricultural valleys, on the basis of historical reasons and further factors that we will explain below.

Among all the patterns developed by Alexander, the one we have focused on is the 'City Country Fingers', based on the country fingers that extend from the suburbs to the city center, and therefore potentially exploitable for the activities listed above. A pattern highly correlated with 'Country Fingers' is the 'Agricultural Valleys', the meaning of which is summarized in Alexander's phrase: 'hills for building, valleys for crops'. Though, the best land for agriculture also seems to be the best for construction even though, once destroyed, it cannot be regained for centuries, according to Alexander. However, there is not always a close correlation between the 'City Country Fingers' and 'Agricultural Valleys' patterns in the development of urban centers. Land use patterns can be viewed as a reflection of various factors including zoning regulations and environmental and social influences (Iwata and Oguchi 2009). In the city of Kamakura, the development of agricultural and urban areas was conditioned by several factors: (i) historically, the need for a natural defense system consisting of hills and forests for the human settlement in the valley; (ii) the rapid increase in population and government regulation in the 1970s led to the construction of low-rise buildings in piedmont areas; (iii) the Bubble Economy created vacant land in highly urbanized lowlands in 1989–94; (iv) land use intensified in most urban areas, although hilly areas were still characterized by low-rise buildings; (v) within the same city, land use choices have been driven by economic interests and the tradition of loose land use regulation in Japan (Iwata and Oguchi 2009). The influence of the aforementioned factors has caused the city of Kamakura to deviate from the 'Agricultural Valleys' pattern, with a prevalent development of urban areas in an extensive alluvial plain.

We have listed the reasons why in the urban development of Kamakura, there is no correlation between the two models 'City Country Fingers' and 'Agricultural Valleys'. Let us consider what would have happened if it was not so. If the 'Agricultural Valleys' scheme had been implemented, the buildings would have been built exclusively in the hilly areas and farmland in the Kamakura's alluvial plain. Probably this choice would have produced even worse consequences than the current urban layout. The reasons for this claim are due to a number of considerations. First of all, the high seismic and tsunami risk that characterizes the Kamakura area. Buildings located in hilly areas would be exposed to the site gemorphological phenomenon generated by the entrapment and consequent amplification of seismic waves due to the particular morphology of the relief. So seismic events already of high magnitude would undergo a further increase in energy in these places, with considerable damage to people and homes. To these would be added further natural phenomena triggered by earthquakes, as the landslides. In the hills surrounding the Kamakura territory, superficial instability could be favored by the nature of the hilly terrain composed of sandstone and mudstone, particularly sensitive to superficial instability.

Furthermore, the central-southern sector of the city of Kamakura is characterized by a high tsunami risk (Wiyono et al. 2014) whose intensity would be further aggravated by the coastal morphology. The coastline around the city is open and concave, which is expected to concentrate a tsunami's energy and likely result in high inundation heights shortly after a near-shore event (Okumura et al. 2017).

The presence of a large agricultural area in the intracoastal area would have serious consequences for the crops, damaging them irreparably. Recent studies on tsunamis that occurred in the past and in present times have shown very serious damage to the land due to the ingress of marine waters into the mainland. After a tsunami, large quantities of sea salt tend to deposit on the ground, salt which then tends to accumulate and concentrate, killing existing plants, including trees, and preventing new ones from growing, to the point of making any cultivation impossible and thus eliminating an important source of livelihood for the affected population, adding more damage to that caused by the impact of the waves (INGV, retrieved from: https://www.ingv.it/cat/en/know-and-defend/know-the-tsunami/the-effects-of-tsunamis).

The results achieved at the end of the processing phase were open to multiple considerations. The different techniques used made it possible to obtain two images 'clean of noise', that is, disturbances due to small areas of passive vegetation within urban centers that alter the analysis and interpretation of the salient features of the image. This was obtained, thanks to the implementation of a NoSQL query, performed on the JSON file in which the coordinates of the boundaries and surfaces covered by urban greenery were stored. The query selected all the green areas with an extension of < 200 pixels (1250 m^2), coloring them in transparent gray, in order to make them belonging to the urban area.

Between the two extreme cases reported in the classification scheme of Fig. 3, there are two further classification levels (medium and low), which can have different shades depending on the lesser or greater consistency of the measured parameters. Fig. 5 describes the two aforementioned cases: Fig. 5a shows an urban center surrounded by vegetation that does not show any intersection with it and which denotes a total absence of adherence to the pattern. In Fig. 5b, an ideal situation with an urban center in which the vegetation, coming from peripheral areas, penetrates from every cardinal point within the city, representing a condition of full adherence to the pattern.

The data interpretation described in the results section highlights two different conditions relating to the intersection between green and urban areas. The first situation found in the Kamakura city and many other cities in Japan concerns country fingers made up of hills covered with woods. The valley areas between contiguous reliefs show a progradation of urban areas which, in continuity with the city center, tend to expand within them according to specific directions. In the city of Kamakura, these extensions, called city fingers, develop mainly along the N–S line. Besides, green covers that include urban fingers are characterized by complex morphologies reminiscent of fractal geometry: each country finger tends to branch out recursively into smaller fingers, giving an articulated appearance to the entire area.

Unlike the previous case, in the Acireale city, the country fingers have a mainly two-dimensional development with the corresponding city fingers surrounded by agricultural land mostly used for the cultivation of citrus fruits (oranges, tangerines and lemons) and low-stemmed plants (vine). The progradation of this type of vegetation cover does not present any structural recursion with country fingers that develop linearly toward the urban center.

The characteristics described in the results section show that, only in part, the parameters used for the Kamakura city agree with the high-level classification. In particular:

i. No country finger respects the minimum width of 1 mile and 55% has a width between 500 and 1000 m.
ii. The country fingers come from only three cardinal points compared with the four required and cover each of them for the entire length.
iii. City fingers fully meet the requirement of a width of not more than 1 mile.
iv. From any neighborhood of the city, it is possible to reach at least one country finger by covering a distance of no more than a mile (about 10 min on foot).

Ultimately, points (i) and (ii) meet the requirements of the medium classification level, while points (iii) and (iv) fully satisfy the requirements of the high classification level. For this reason, the city of Kamakura can be attributed to a medium-high level of adherence to the 'City Country Fingers' pattern.

For the urban area of Acireale, however, conformity with the Alexander pattern has an obvious limitation due to the narrow surfaces covered by the country fingers within the urban center. Although they come from three distinct cardinal points, they do not reach the minimum coverage conditions (50%) required for the low classification level. The other parameters, however, fall within the standard requirements of the average classification level. For this series of considerations, therefore, the city of Acireale was classified with a medium-low level of adherence to the pattern.

Conclusions

Classifying urban areas by considering intersections with country spaces from peripheral areas can be considered an efficient method to define the livability of a medium-large city. Having access to rural areas intercalated within cities allows you to improve the quality of life of the inhabitants: one of the main advantages is the possibility of the frequent contact with nature without having to undertake prolonged and stressful journeys when they are in remote areas.

Country fingers embedded in an urban center give significant results both in the environmental and social fields, including better air quality, the regulation of the microclimate, the promotion of environmental education for children and a better relationship between humans and nature.

In some parts of the world, urban agriculture has become a fashionable phenomenon, linked to greater awareness and attention to the production processes of genuine and sustainable food products. In the two cases dealt with, we do not have greenhouse agriculture but true agriculture, made up of countryside and lots of agricultural land, woods and animals, farms surrounded by greenery just a few minutes from the city center.

We have defined this way of exploiting the green areas that extend within the urban center as active, different from the green that is used passively, in order to promote the well-being of the inhabitants. We can observe that several cities, especially in Japan, have developed their urban territory following this model.

To establish the adherence of an inhabited center to the ‘City Country Fingers’ model, we have created a method and a classification scheme based on AGA, considered to have greater potential than the classic ones represented by parks and public gardens. This method lets you automate the classification process through a Python application. Thanks to that it has been possible to reduce the time required to label and recognize the limit of the green areas from the urban ones by simplifying the morphometric analysis of each of them. In the analyzed cities, two main morphologies relating to the country fingers consisting of wooded reliefs and agricultural land were recognized. The first frequently present a three-dimensional development with fractal-like geometry that recursively tends to reproduce itself. In this way, various branches of the main country finger are generated, within which smaller city fingers, organized hierarchically, develop (Fig. 6a and b). The latter has a planar development and a linear structure with a hierarchical organization of the country and city fingers practically absent (Fig. 6c).

Note that the three-dimensional morphologies of the country fingers allows the populations to have a more immersive relationship with nature due to the particular location of the houses surrounded by woods (Fig. 6a and b). However, there could be some disadvantages. We refer, in particular, to nations characterized by high seismic and volcanic risk in which high-magnitude earthquakes can trigger destructive landslides for the houses in the city fingers. Also, the city fingers represent areas of rainwater channeling that can favor flooding and the formation of debris flows. A further factor that penalizes these areas is that, in particular catastrophic events (earthquakes, eruptions, floods, etc.) or the immediacy of them, the city fingers can represent a bottleneck for the evacuation of the resident population.

The location of the urban areas in the hilly areas and of the agricultural land in the coastal plain of Kamakura, according to the ‘Agricultural Valleys’ pattern, would not have improved the situation anyway but would, in some respects, have worsened it. The coastal areas of Japan and, in particular, the alluvial plain of Kamakura, could suffer enormous damage to crops in the presence of a tsunami. The particular morphological conformation of the coastline would enhance the amplitude of the sea waves, increasing their energy. The salinized soils from the ingress of the waves would require several years and huge economic resources to be reclaimed.

Probably the best urban planning choice can be considered a middle way between the ‘Agricultural Valleys’ pattern and the current conformation: maintaining the current urban layout by concentrating agricultural areas in the distal sectors. In this way, human lives could be saved with the adoption of alarm systems already widely used, while the agricultural areas, located in the current northern urban part, would be preserved thanks to the considerable distance from the coast line.

The same considerations can be extended to the area of Acireale, a coastal town which, as in the previous case, is characterized by a high tsunami, seismic, volcanic and hydrogeological risk. Some differences, compared with the territory of Kamakura, are to be attributed to country fingers developed in

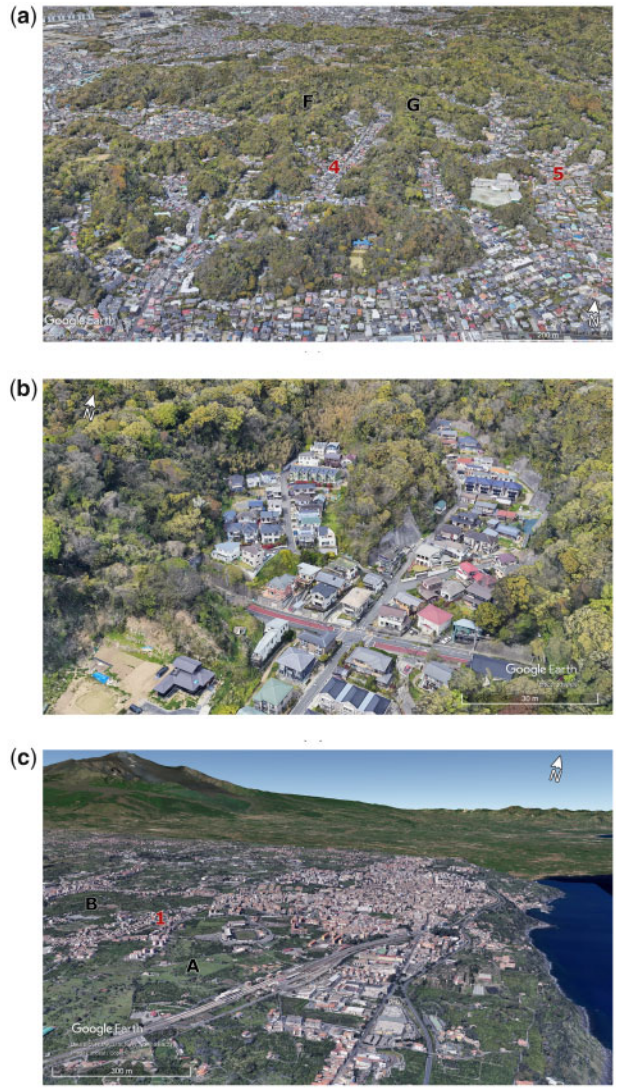

Figure 6: Three images of the territories under analysis: (a) suggestive three-dimensional image of country and city fingers (F–G and 4–5 respectively) in the city of Kamakura; (b) Terminal part of a city finger that branches into two parts (to the right of F in the previous image); (c) The city of Acireale seen from the south-east where it is possible to observe country and city fingers (A–B and 1 respectively). In the background, the Etna volcano. For references to country and city fingers, see Fig. 4

two dimensions (agricultural land), in which the energy of the relief is canceled (Fig. 6c). In this case, the appearance of the urban area is undoubtedly less impressive, but the previously exposed risk factors are of lesser entity.

Keep in mind, however, that for years, several cities, especially in Japan, have embodied the model of urban development founded on city and country fingers. The concept introduced by Christopher Alexander in 1977, on which the ‘City Country Fingers’ pattern was developed, was based on an ideal situation with the urban area intersected by country fingers from all directions and prograding toward the city center (Fig. 5b). Tests carried out on the cities of Acireale and Kamakura used a classification model founded on this pattern, obtaining conflicting results. In the first case, the distribution model of the urban area concerning the vegetation cover indicates a limited overlap with the 'City Country Fingers' pattern, with few intersections relegated mostly to the northern and southern sectors of the Acireale city. On the contrary, the urban center of Kamakura is close to the ideal case proposed by Alexander with a high density of country fingers that penetrate the inner city.

To verify the reliability of the method, the application was tested only in the urban centers of Acireale and Kamakura, but it is not excluded that in the future, it will be extended to the entire territory in which the cities extend.

The possibility to use images that can be downloaded for free from Google Earth, on which to start an image processing analysis capable of evaluating, in a few seconds, the correspondence to the 'City Country Fingers' pattern is the strength of the method. Evaluation of this type could prove advantageous to establish the livability of a city and the neighborhoods in it, for territorial planning and/or to establish different levels of value of buildings based on their position within the city.

Data availability

Raw data are available on reasonable request.

Conflict of interest statement. None declared.

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