Powering Trentino: large-scale detailed estimation of the photovoltaic potential of the entire province

Integrated Photovoltaic Conference

PROVINCIA AUTONOMA DI TRENTO

aprie

FONDAZIONE BRUNO KESSLER

3DOM 3D OPTICAL METROLOGY

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Among the strategic objectives of the 2021-2030 PEAP is the increase of renewable energy production: it is planned for 2030

+13,4 % **of renewable energy used compared to 2016 (reaching 48.2%)**

The photovoltaic source is one of those on which PEAP focuses, both in terms of space availability and ease of installation.

In order to respond to national regulations, having identified “suitable areas” that must allow us to install the power that is required of us, we asked ourselves the following questions:

How much power would we have if we covered all suitable areas in Trentino with photovoltaic panels?

The Fondazione Bruno Kessler, and in particular the 3DOM (3D Optical metrology) unit, was commissioned to compute the PV producibility by exploiting several geospatial data from the provincial database of the Province and AI solutions.

The objectives of the work were:

- to **compute the solar irradiation** (raster maps at 1 m resolution), taking into account close and geographic obstacles in the shadowing estimation (mountains, trees, buildings, chimneys)
- automatically **identify the panels already installed**;
- calculate the **energy production and installable power on suitable surfaces**

Challenges:

- Project scale: Trentino province ≈ 6200 sqkm and 166 municipalities
- Manage the huge amount of data
- Automatize data processing – large scale project
- Complex morphology: consider all the occlusions for computing the solar irradiation (multi-scalar approach)

Alpine territory - mountains

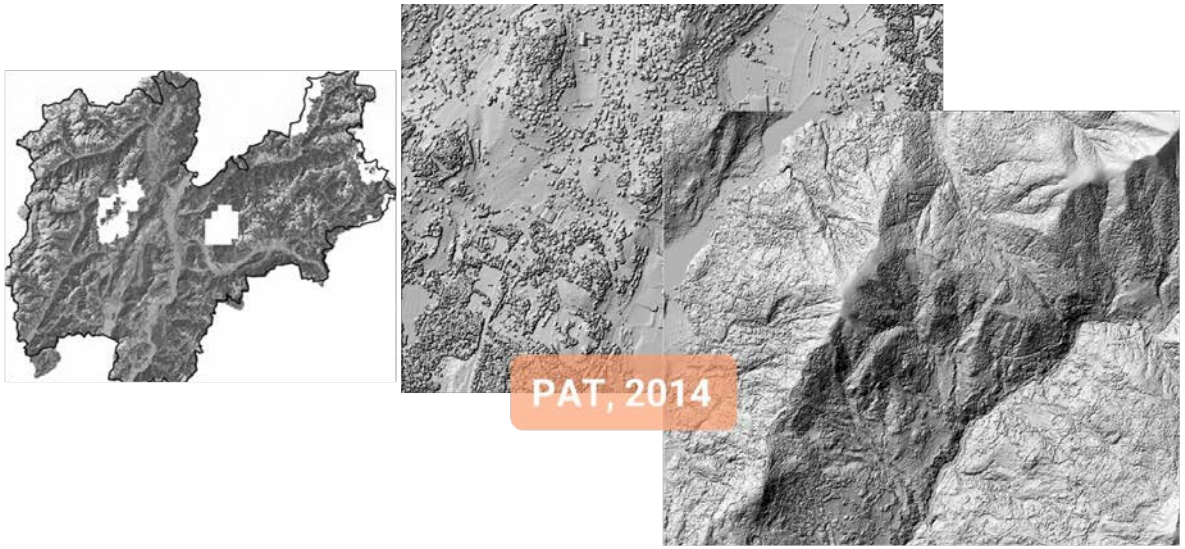
Near objects (buildings, trees, chimneys, etc.)

PV project data

Digital Surface Models (DSM)

- LiDAR 2014 (PAT), 1 m
- LiDAR 2011 (PAT), 1m
- EuroDEM, 30 m

to compute the solar irradiation



Vector data

- Municipal boundaries
- Building footprints (2017)
- Protected areas and buildings
- Land use and other thematic maps

to select the suitable areas

Orthophotos

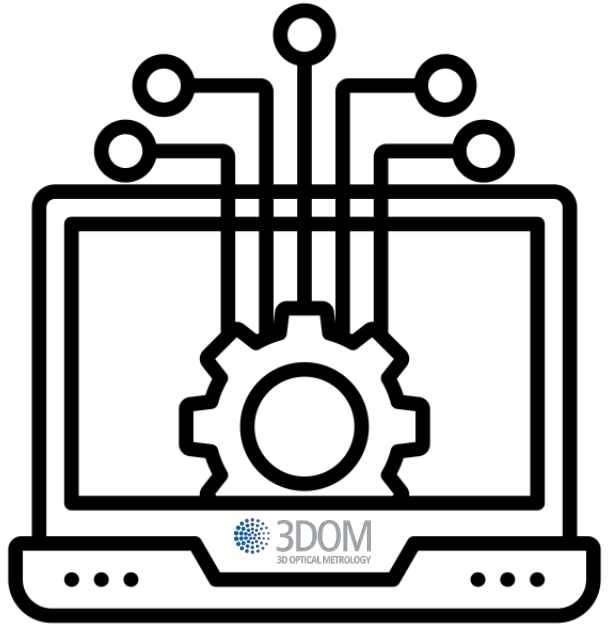
- PAT, 2015 (20 cm)
- AGEA, 2020 (20 cm)

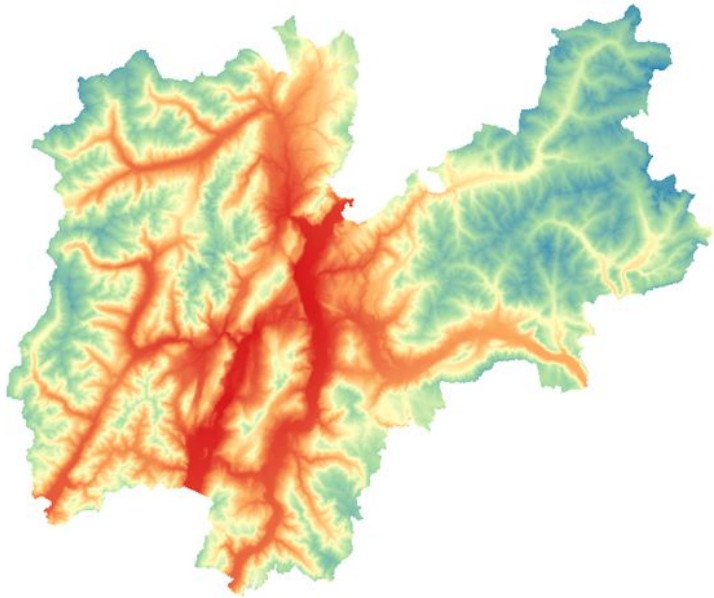
to select the installed pv and recent buildings

INPUT

Data Raster - DGP:

- LIDAR 2014 (and 2011)
- Ortophoto PAT 2015
- Ortophoto AGEA 2020

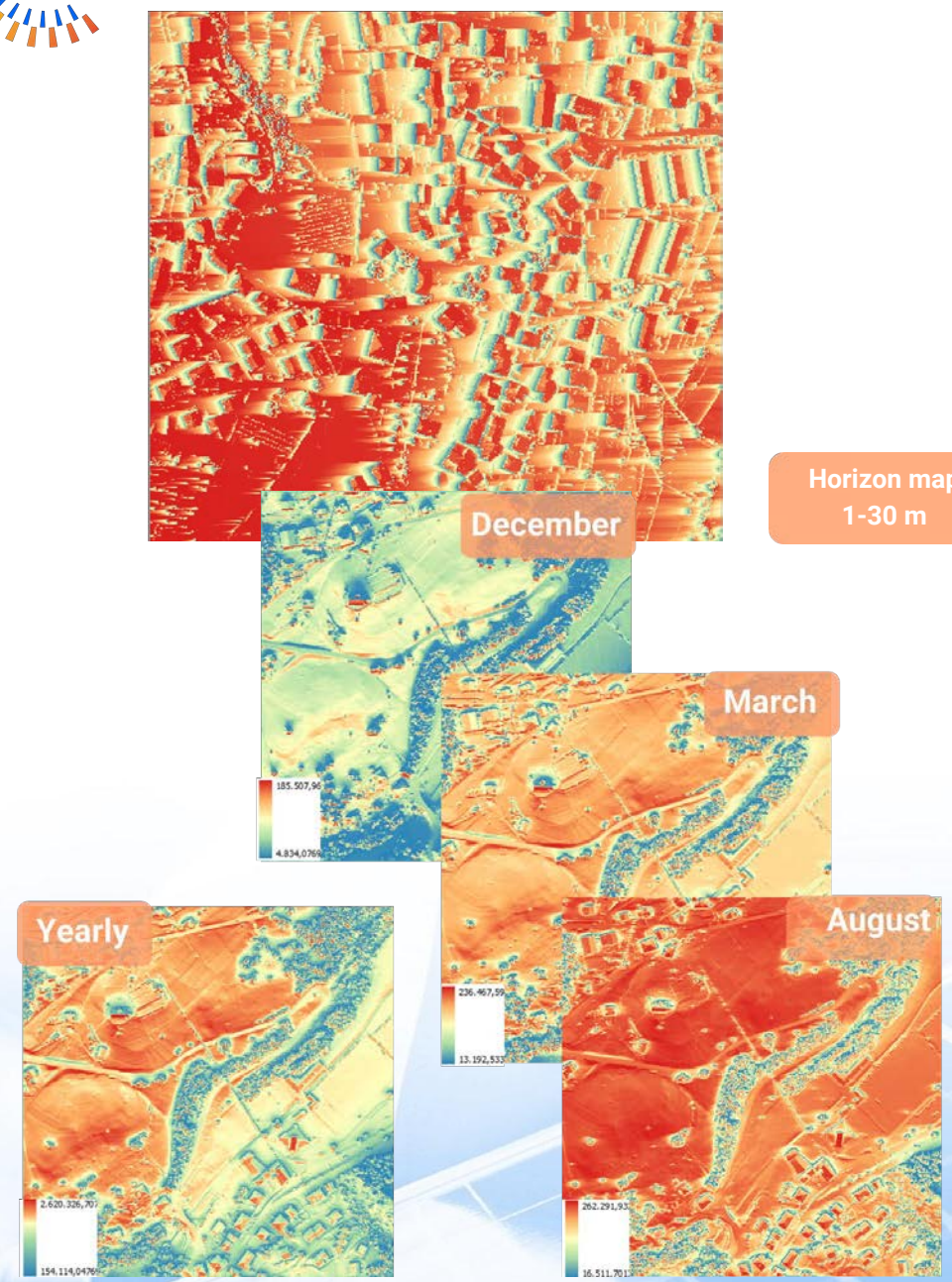




OUTPUT

Solar irradiation raster maps of the entire Trentino (excluding some sparsely populated areas of the Dolomites) with a "clear-sky" assumption (1 m resolution)

Solar irradiation extimation



Horizon calculation

GRASS r.horizon for the horizon maps using a combination of the DEM at 30m resolution and the DSM from the 2014 Lidar flight at 1 m

Solar irradiation calculation

GRASS GIS r.sun for irradiation maps using input horizon maps and DSM from Lidar flight 2014 at 1 m

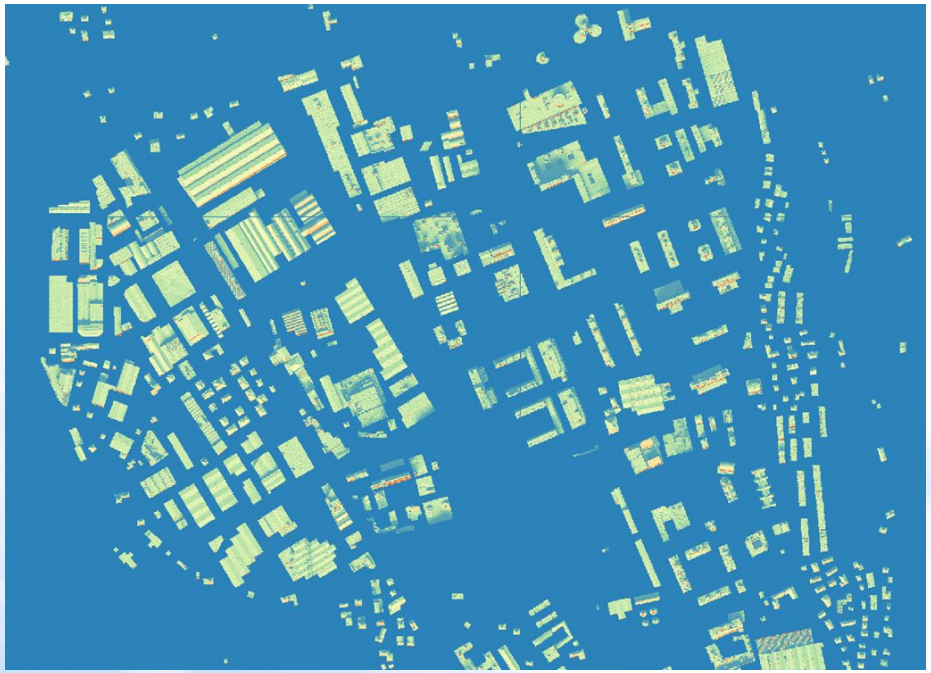
- **9 million global irradiation maps for each DSM** tile (500x500m) **for each day of the year with clear-sky assumption**
- aggregated on a monthly (cumulative daily averages) and annual basis (sum of cumulative monthly values)
- grouping by municipality

Selection of eligible areas

SUITABLE AREAS

Legge Provinciale 2 maggio 2022 n. 4

a) areas for infrastructure services and landfills;
b) industrial-craft productive areas;
c) mixed commercial, tertiary and productive areas
d) actual mining areas and quarries;
e) sites yet to be reclaimed of national interest [...] and identified sites of local interest;
f) uncontrolled and reclaimed landfills [...];
g) service areas for mobility
h) ~~existing roads or roads to be upgraded;~~
i) parking areas

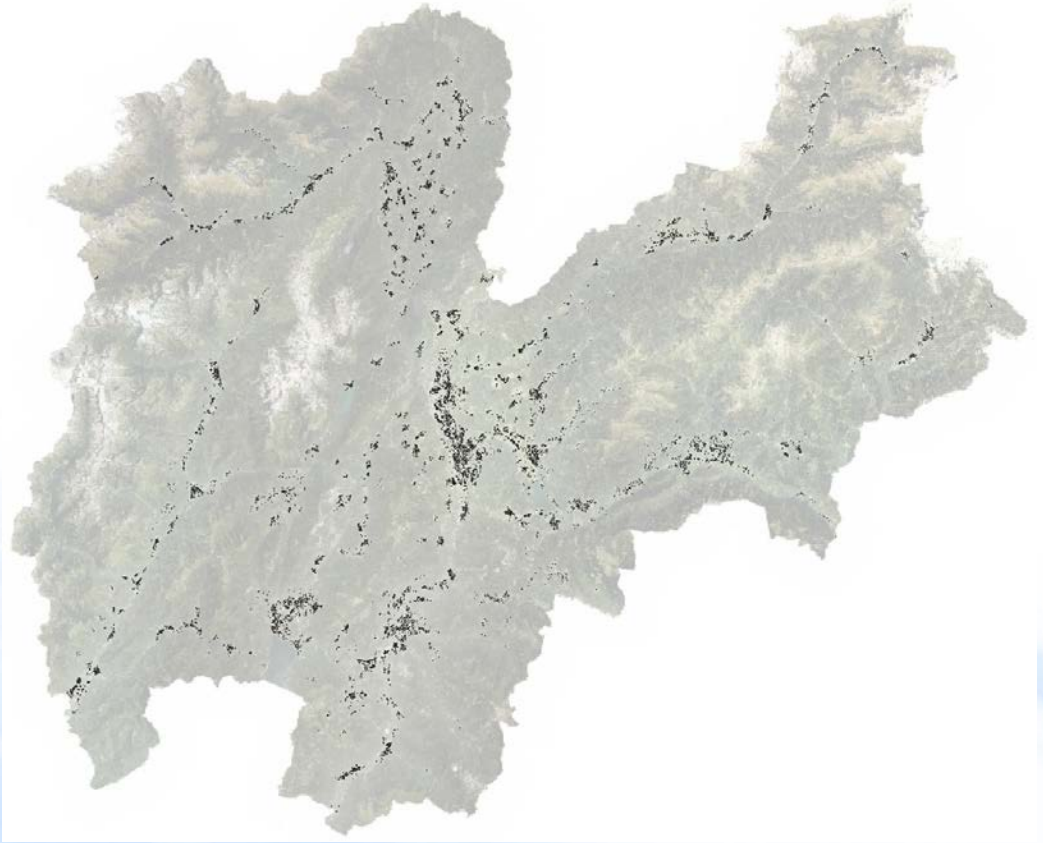


Installed PV panels identification

- Automatic detection with AI solution of the installed panels (orthophotos)
- Iterative procedure for improving the neural network
- Generation of vector data/masks to subtract to the suitable areas

DATA INPUT
a) PAT orthophoto, 2015, with 20 cm resolution;
b) AGEA orthophoto, 2020, with 20 cm resolution.

OUTPUT:
vector masks for the recalculation of irradiation on free-coverage areas only



New buildings identification

BUILDINGS

All the roofs of the buildings identified by the 2015 and 2020 orthophotos have been counted, minus the panels already installed.

EDIFICI	-	EDIFICI VINCOLATI	-	PANNELLI GIA' INSTALLATI	=	SUPERFICIE DISPONIBILE SULLE COPERTURE DELLE COSTRUZIONI ESISTENTI
(da CSP + edifici riconosciuti in ortofoto 2020)		(dalla Soprintendenza per i beni culturali ai sensi del Codice dei beni culturali e paesaggio)		(riconosciuti da ortofoto dal sistema di FBK)		

A new vector shape 'buildings 2020' was created by integrating the previous map with the existing buildings as of 2020 but without the listed buildings.

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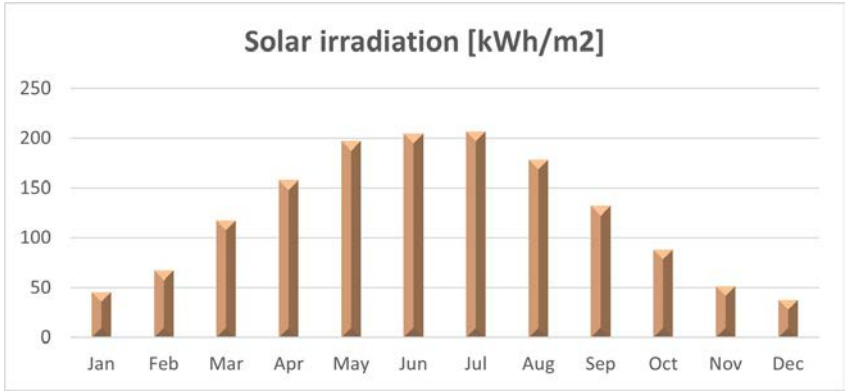
Correction Factors

kc *(clear sky index)*	A correction factor calculated for each municipality, which ranges between 0.2 and 0.79 and takes into account the cloudiness data to be applied to the *clear sky* values.
60% of surfaces	Amount of areas considered really available for new panels installation on the rooftops after adding some installation constraints (low solar irradiation, distance from the building borders, etc.)
Pv performance	Based on available scientific reports on the efficiency of photovoltaic panels, an average value of 80% was chosen. A standard value of 1000 kWh/kWp was considered as the producibility value, although we verified from GSE data that the average producibility is around 1050 kWh/kWp.

Model assumptions

Pv panel location	horizontal and adherent to the surface
Shading	Input data LiDAR flight 2014 with obstacles (such as trees, artefacts and structures) that could create shadows on the ground

Calculation method



Solar irradiation [kWh/sq m].

The amount of solar energy hitting the surfaces. Monthly and yearly values per municipality are provided

Productivity [kWh/sq m]

Producible energy calculated as:

$$E=A*r*H*Pr$$

A= total panel area
r= panel efficiency (20%)
H= global irradiation
Pr= performance ratio (80%)

Nominal Power:

Power of a photovoltaic system that can be installed:

$$Pn= r*A*G_{stc}$$

G_{stc}= irradiation under standard conditions (1000 W/sqm)

Energy yield [kWh/kW] Y= Pr*H

Electricity production [kWh] E*= Pn* Y

Surface of suitable areas in Trentino

	SUITABLE AREA IN TRENTINO			
	TOTAL (ROOFS AND ELIGIBLE AREAS)	ROOFS	ELIGIBLE AREAS	AREAS WITH INSTALLED PLANTS
m^2	80.301.324,50	38.657.174,76	50.891.107,00	1.111.530,00
km^2	80,30	38,66	50,89	1,11

To succeed in meeting the target, we will need to install the same area of panels each year until 2030 as we do today;

Total potential power in Trentino

	TOTAL		ROOFS		ELIGIBLE AREAS	
	Pn	[GWh]	Pn	[GWh]	Pn	[GWh]
kW	9.502.775,34	7884,51	4.505.477,37	3869,79	6.047.105,40	4817,29
MW	9.502,78		4.505,48		6.047,11	
GW	**9,50**		**4,51**		**6,05**	

With the identified areas we would have about 10 times the power we need. Taking into account the simplifications and the fact that not all areas are immediately usable, the figure allows us to be confident that we can achieve the goal.

Results for Municipalities (TABELLA)

	A	B	R	S	T	U	V	W	X	Y	Z	AA	AB
1			Clear Sky * Kc										
2	COMUNE	Month / Year	Aree Idonee Totali			Solo Edifici					Altre Aree Idonee (Parcheggi, zone pro		
3			Potenza Nominale (KWp)	Resa Energetica (KWh/KWp)	Produzione Elettricità (GWh)	Irraggiamento Solare (Wh/m^2)	Producibilità (Wh/m^2)	Potenza Nominale (KWp)	Resa Energetica (KWh/KWp)	Produzione Elettricità (GWh)	Irraggiamento Solare (Wh/m^2)	Producibilità (Wh/m^2)	Potenza Nominale (KWp)	Res (K
4	ala	january	205626,960	28,811	5,924	37539,562	6006,330	72217,280	30,032	2,169	29523,248	4723,720	154379,280	
5		february		35,276	7,254	45696,259	7311,401		36,557	2,640	37879,320	6060,691		
6		march		68,155	14,015	87756,980	14041,117		70,206	5,070	77010,601	12321,696		
7		april		85,228	17,525	109020,069	17443,211		87,216	6,299	100012,230	16001,957		
8		may		92,996	19,122	118384,182	18941,469		94,707	6,840	112075,002	17932,000		
9		june		109,408	22,497	138950,189	22232,030		111,160	8,028	133399,972	21343,996		
10		july		112,828	23,201	143525,692	22964,111		114,821	8,292	136809,885	21889,582		
11		august		98,525	20,259	125843,514	20134,962		100,675	7,270	116870,880	18699,341		
12		september		71,127	14,626	91428,051	14628,488		73,142	5,282	81379,473	13020,716		
13		october		48,722	10,018	62895,068	10063,211		50,316	3,634	53762,129	8601,941		
14		november		27,233	5,600	35413,385	5666,142		28,331	2,046	28239,822	4518,372		
15		december		23,064	4,743	30157,099	4825,136		24,126	1,742	23222,944	3715,671		
16		year		810,350	166,630	1037974,311	166075,890		830,379	59,968	941366,899	150618,704		
17	albiano	january	251064,120	16,518	4,147	25476,281	4076,205	17054,400	20,381	0,348	18803,958	3008,633	239043,480	
18		february		30,294	7,606	48299,094	7727,855		38,639	0,659	33804,943	5408,791		
19		march		61,954	15,554	96815,553	15490,489		77,452	1,321	70924,583	11347,933		
20		april		81,894	20,561	122901,949	19664,312		98,322	1,677	96601,581	15456,253		
21		may		99,146	24,892	144223,534	23075,765		115,379	1,968	118728,890	18996,622		
22		june		116,600	29,274	167830,745	26852,919		134,265	2,290	140424,866	22467,978		
23		july		117,538	29,510	170465,615	27274,498		136,372	2,326	141036,378	22565,820		
24		august		100,514	25,235	149426,250	23908,200		119,541	2,039	119191,500	19070,640		
25		september		68,467	17,190	106556,313	17049,010		85,245	1,454	79046,062	12647,370		
26		october		38,103	9,566	60293,597	9646,975		48,235	0,823	42847,930	6855,669		
27		november		15,369	3,859	24205,911	3872,946		19,365	0,330	17326,821	2772,291		
28		december		12,324	3,094	18516,786	2962,686		14,813	0,253	14127,940	2260,470		
29		year		748,714	187,975	1119797,074	179167,532		895,838	15,278	881118,608	140978,977		

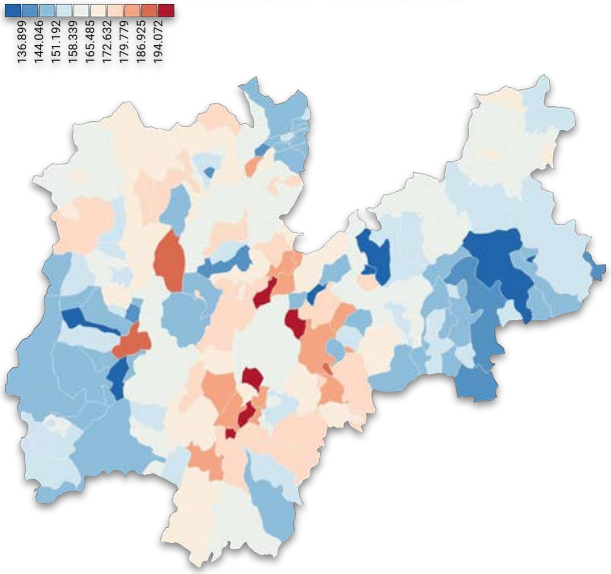
Visualization of results

3 MUNICIPALITIES WITH HIGHER POTENTIAL POWER						
COMUNE	**solar irradiation** [kWh/m^2]	**Production** [kWh/m^2]	**Area** [m^2]	**Pn** [kW]	**Performance** [kWh/kW]	[MWh]
TRENTO	1.170,48	187,28	4.701.464	550.094,82	936,38	515.098,75
ROVERETO	1.103,02	176,48	3.965.451	469.098,12	882,42	413.940,20
PREDAIA	995,08	159,21	2.428.056	287.963,88	796,06	229.237,83

3 MUNICIPALITIES WITH LOWEST POTENTIAL POWER						
COMUNE	**Irraggiamento Solare** [kWh/m^2]V	**Producibilità** [kWh/m^2]	**Area** [m^2]	**Potenza Nominale** [kW]	**Resa Energetica** [kWh/kW]	**Produzione Elettricità** [MWh]
MASSIMENO	914,30	146,29	21.107	2.526,72	731,44	1,85
SAGRON MIS	862,50	138,00	32.288	3.851,28	690,00	2,66
CAVIZZANA	899,97	144,00	37.750	4.517,40	719,98	3,25

Comuni e producibilità totale aree idonee

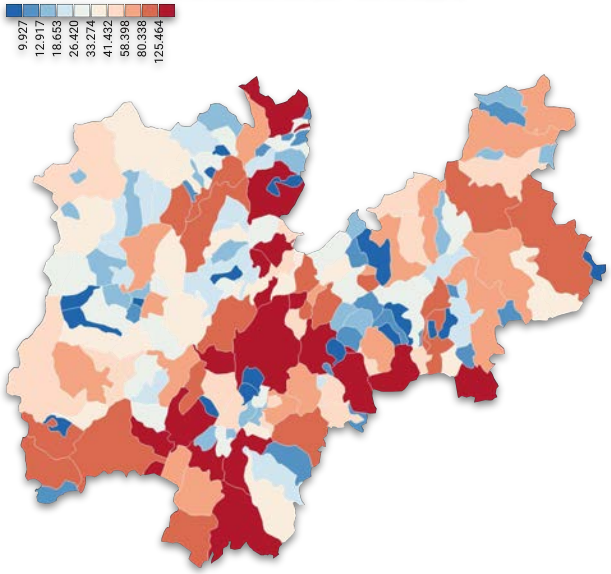
Valore di producibilità totale delle aree (coperture + aree idonee) [Wh/mq]



Fonte: PAT-APRIE + FBK • Creato con Datawrapper

Comuni e potenza installabile

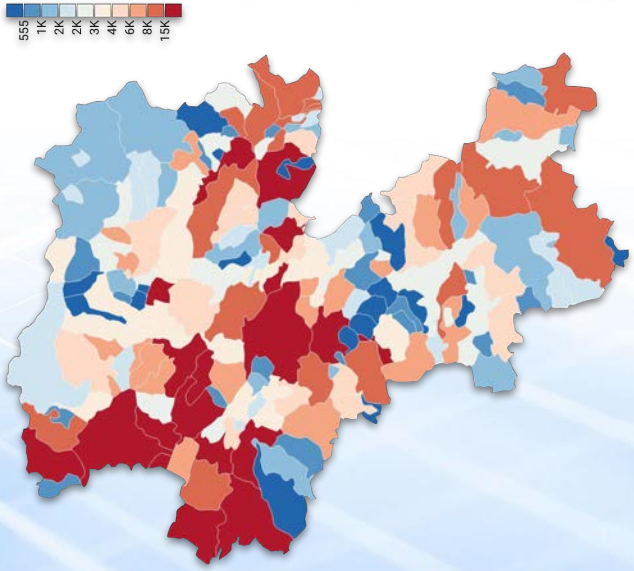
Valore di potenza installabile sul totale delle aree (tetti + aree idonee) [kW]



Fonte: PAT-APRIE+FBK • Creato con Datawrapper

Superficie di fotovoltaico installato sulle coperture

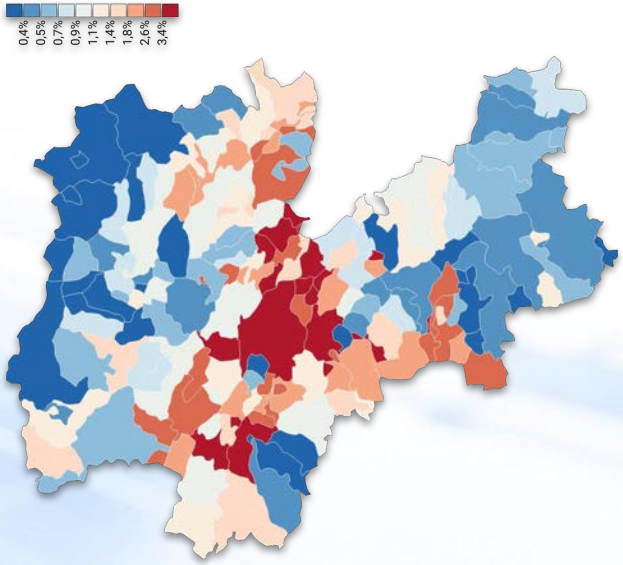
Impianti fotovoltaici installati sulle coperture al 2020 (da riconoscimento tramite ortofoto) [mq]



Created with Datawrapper

% superficie idonea su superficie comunale

rapporto tra la superficie idonea all'installazione di impianti FV (tetti + aree idonee) e superficie comunale



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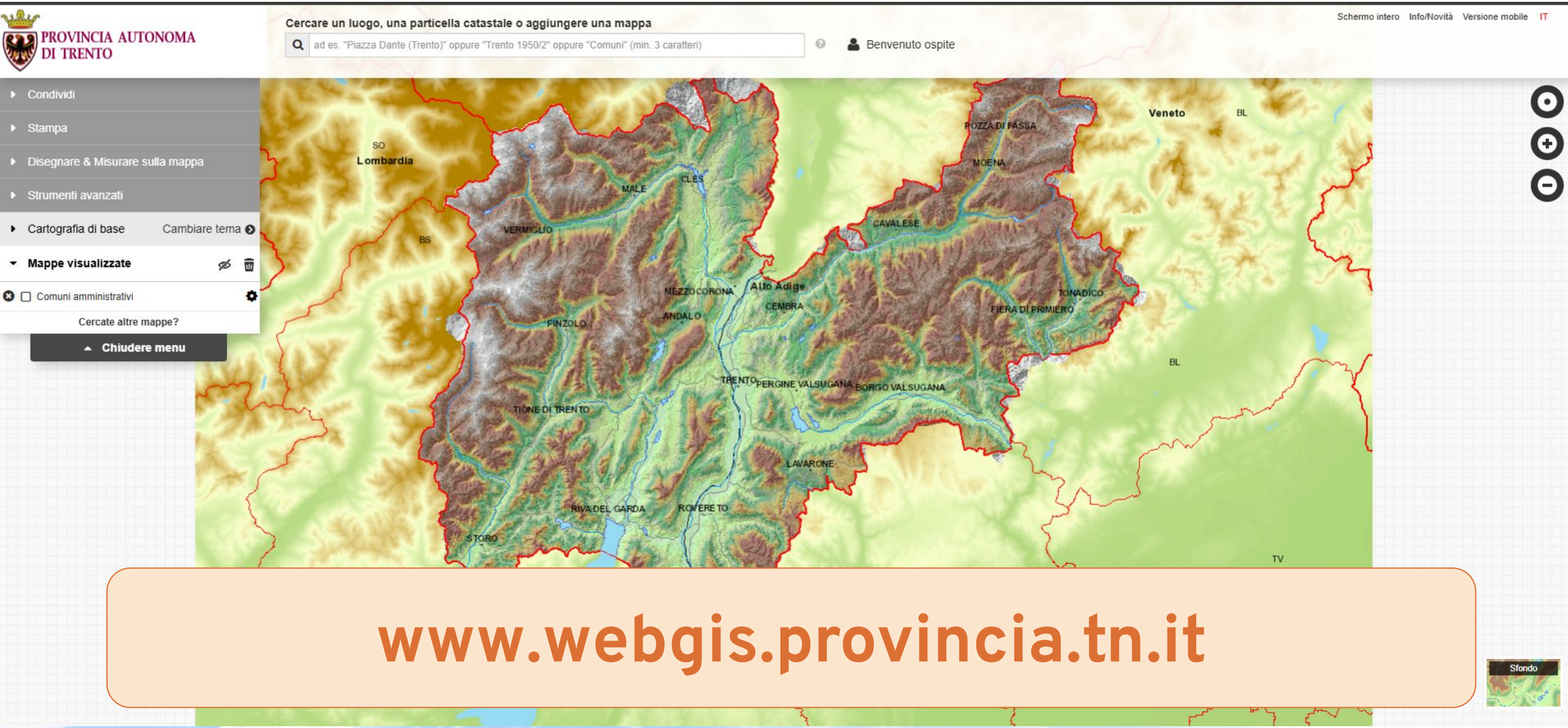
Map on public [WEBGIS]



www.webgis.provincia.tn.it

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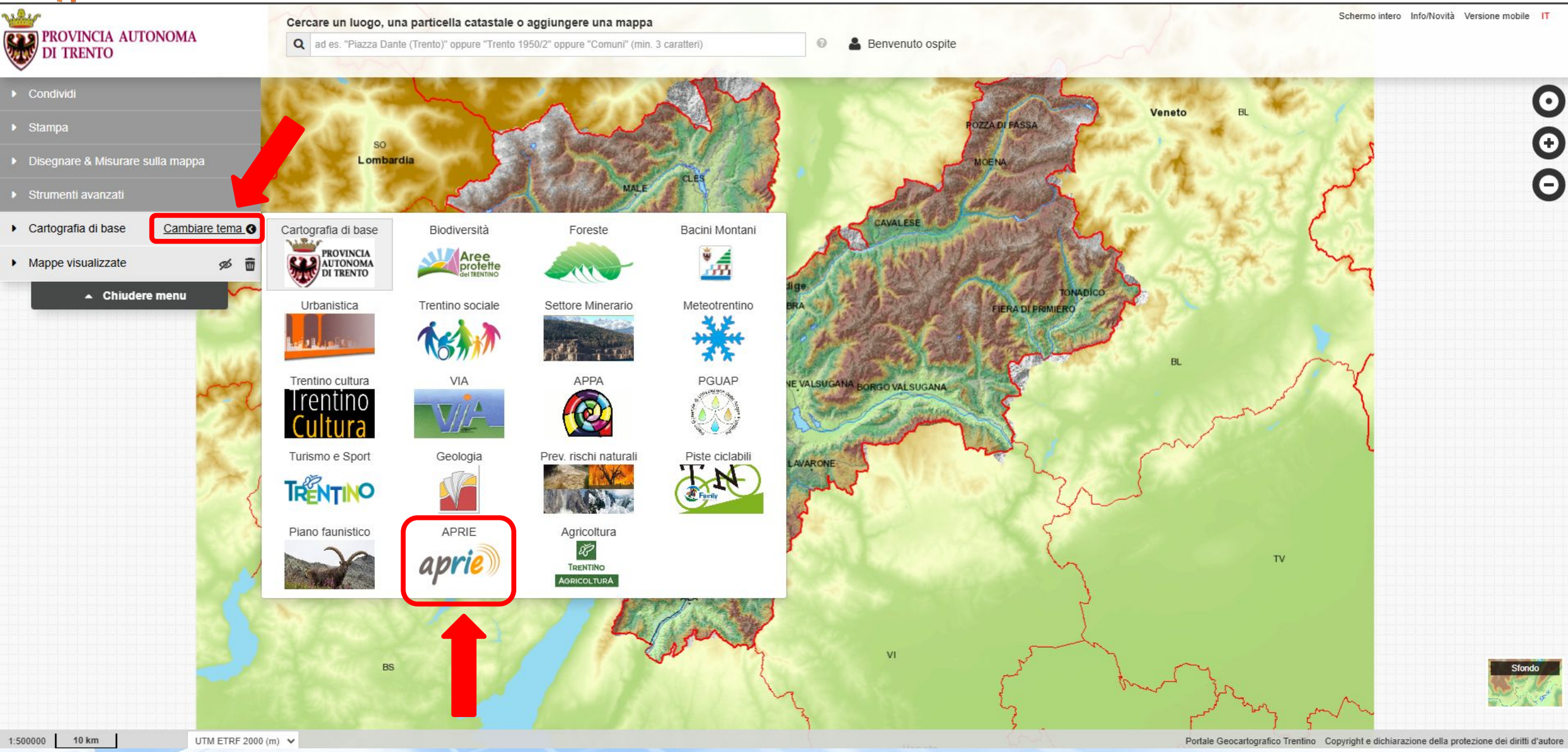

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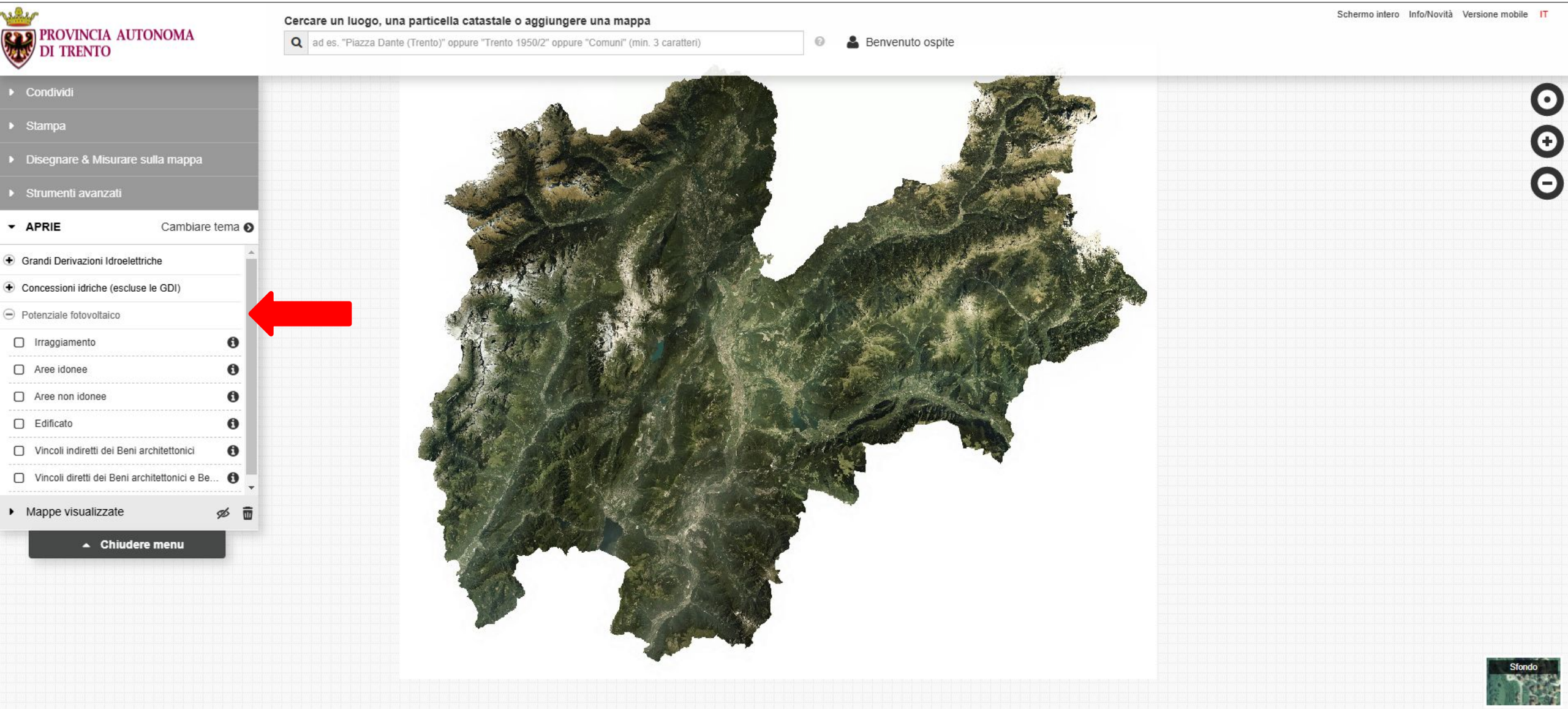

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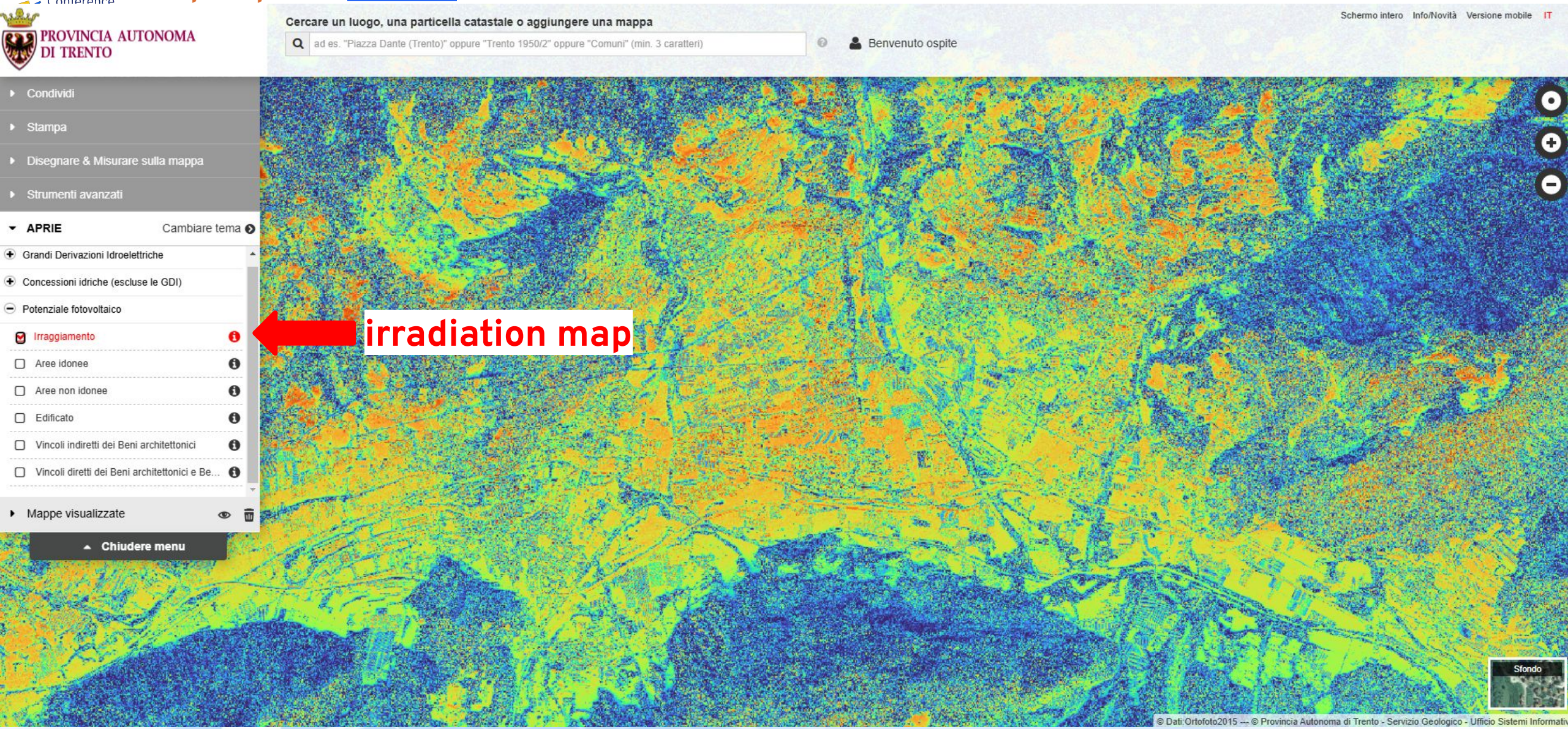

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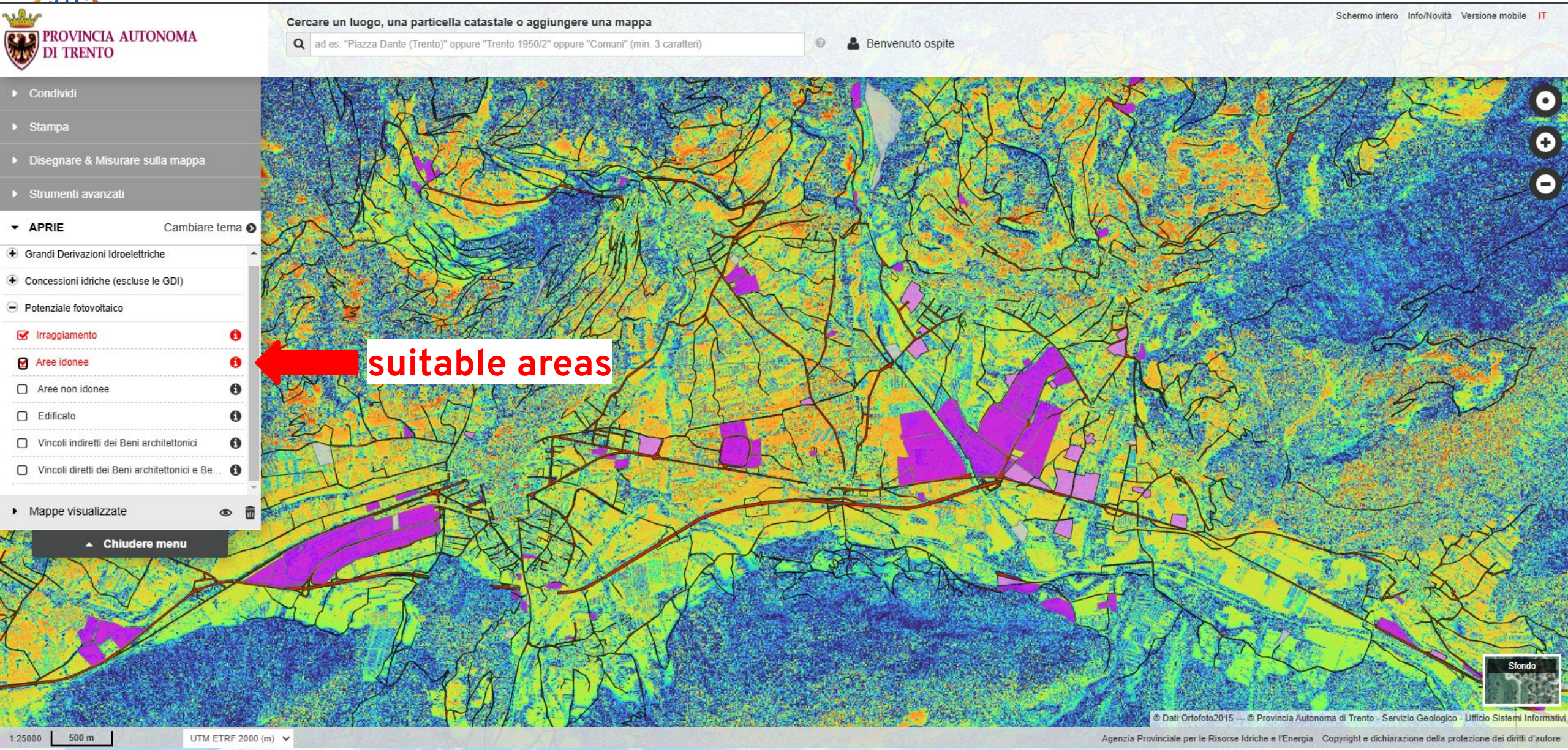

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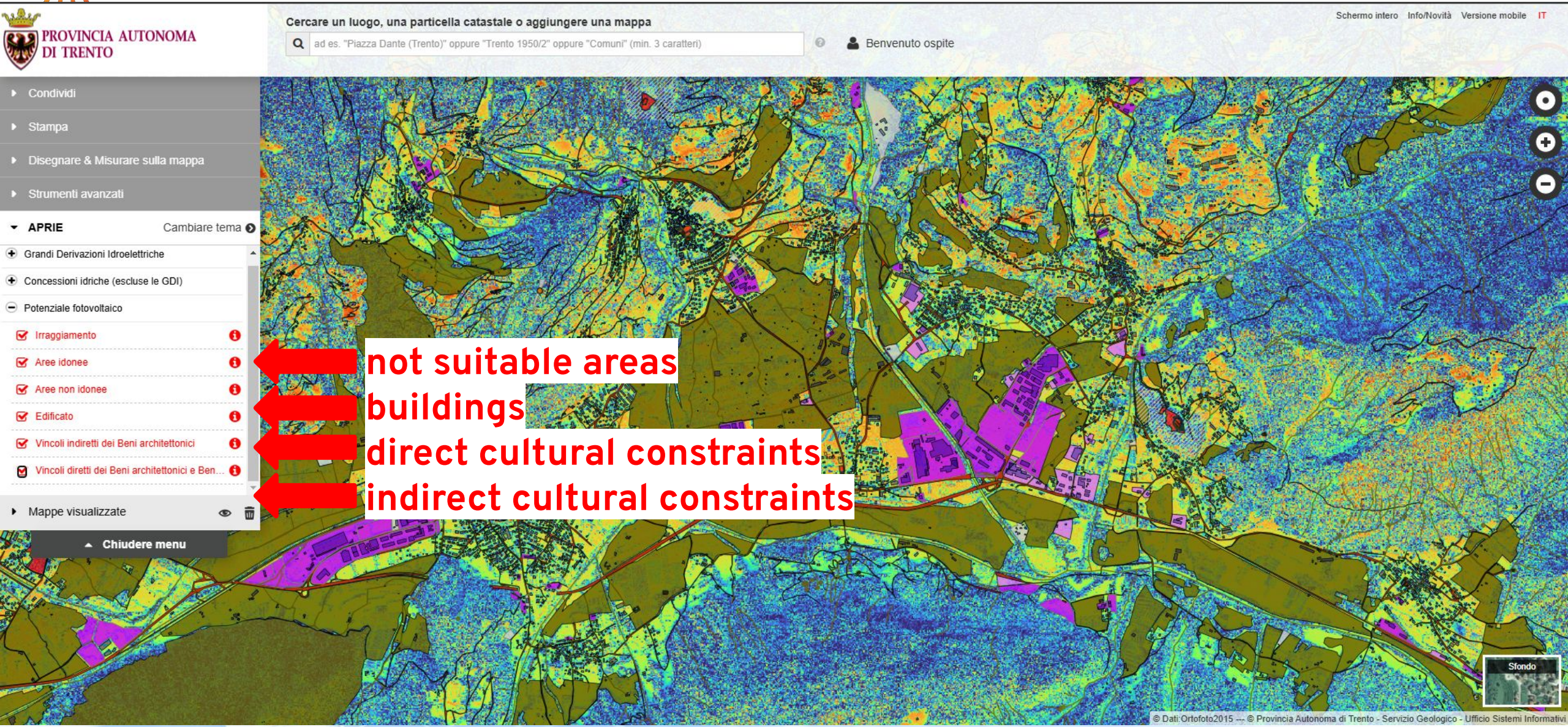

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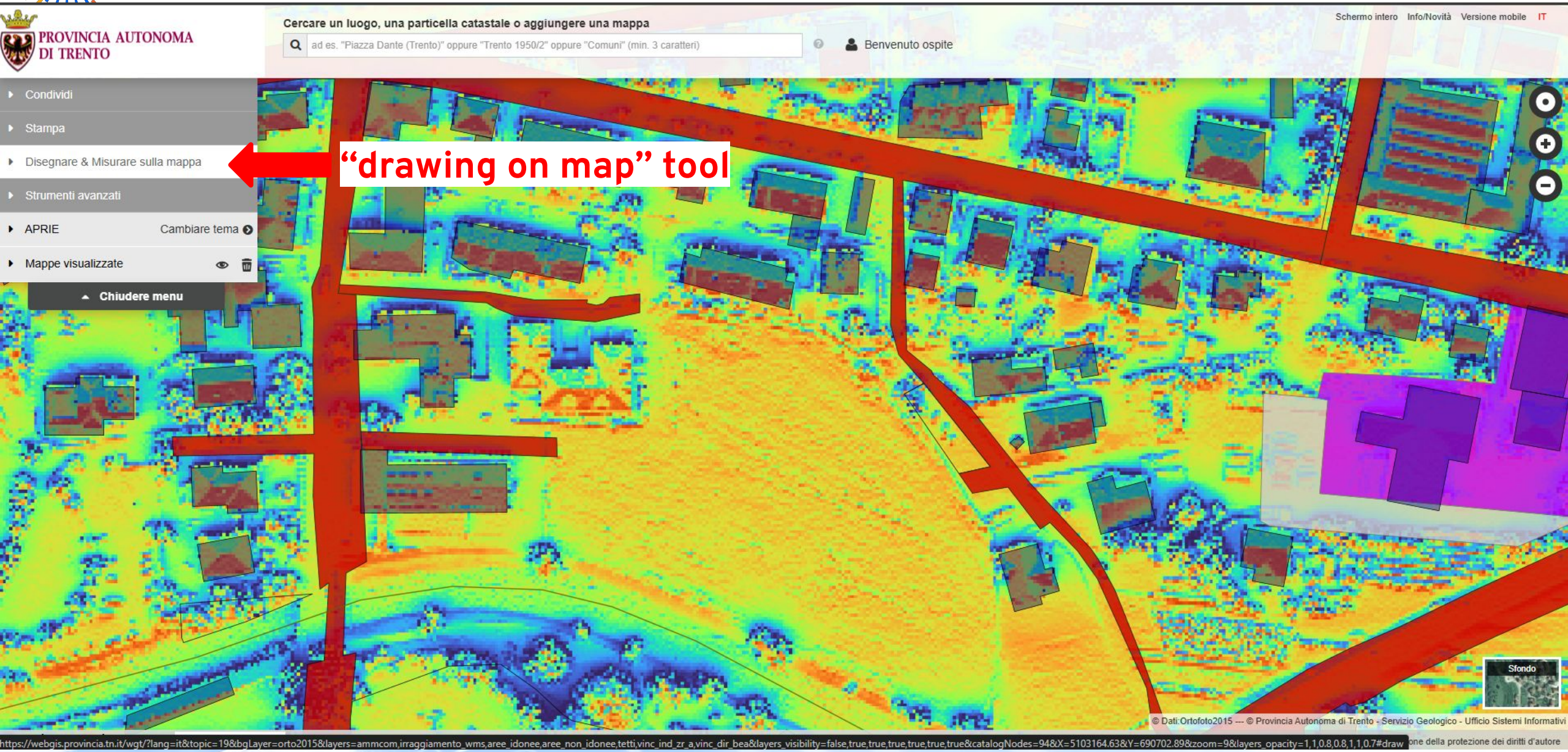

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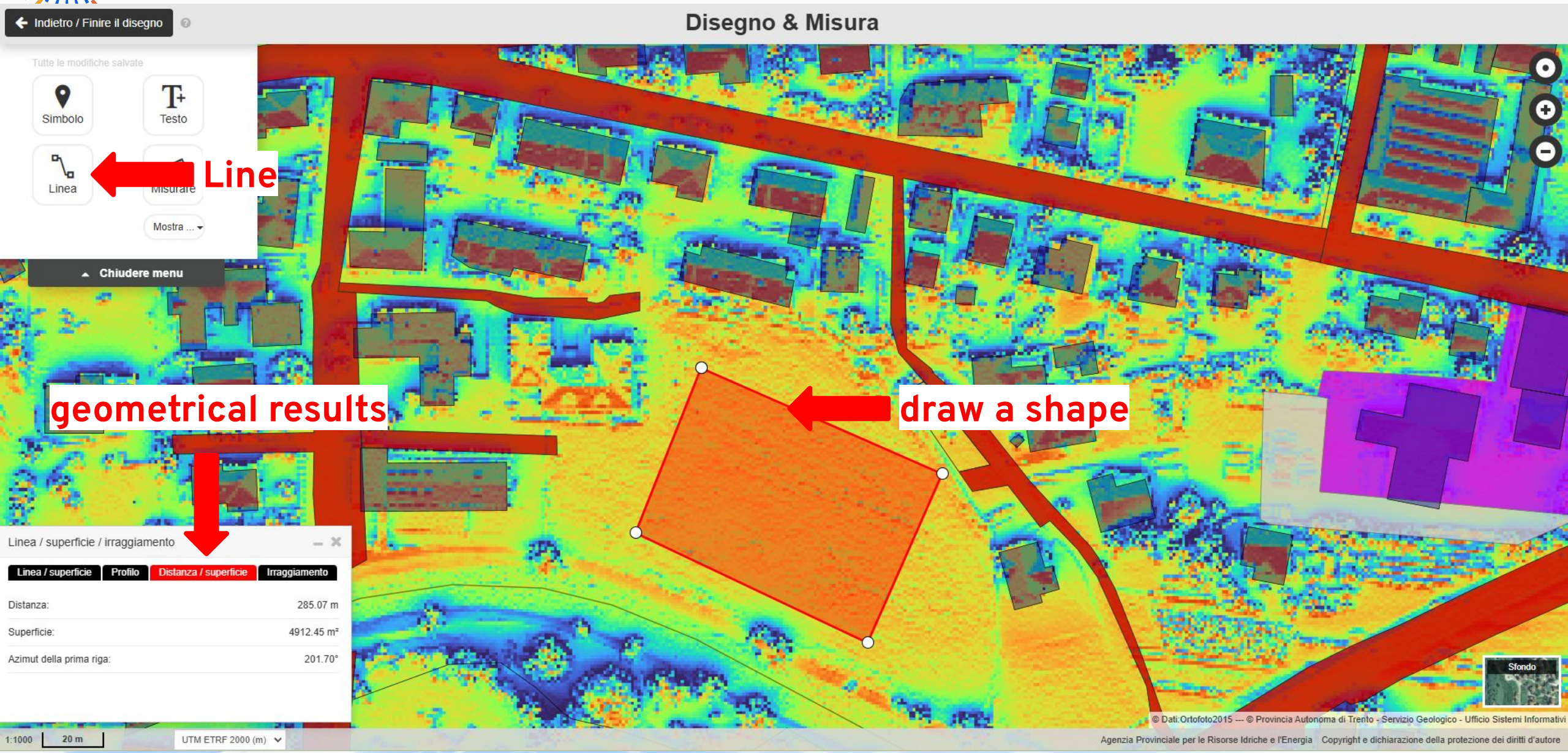

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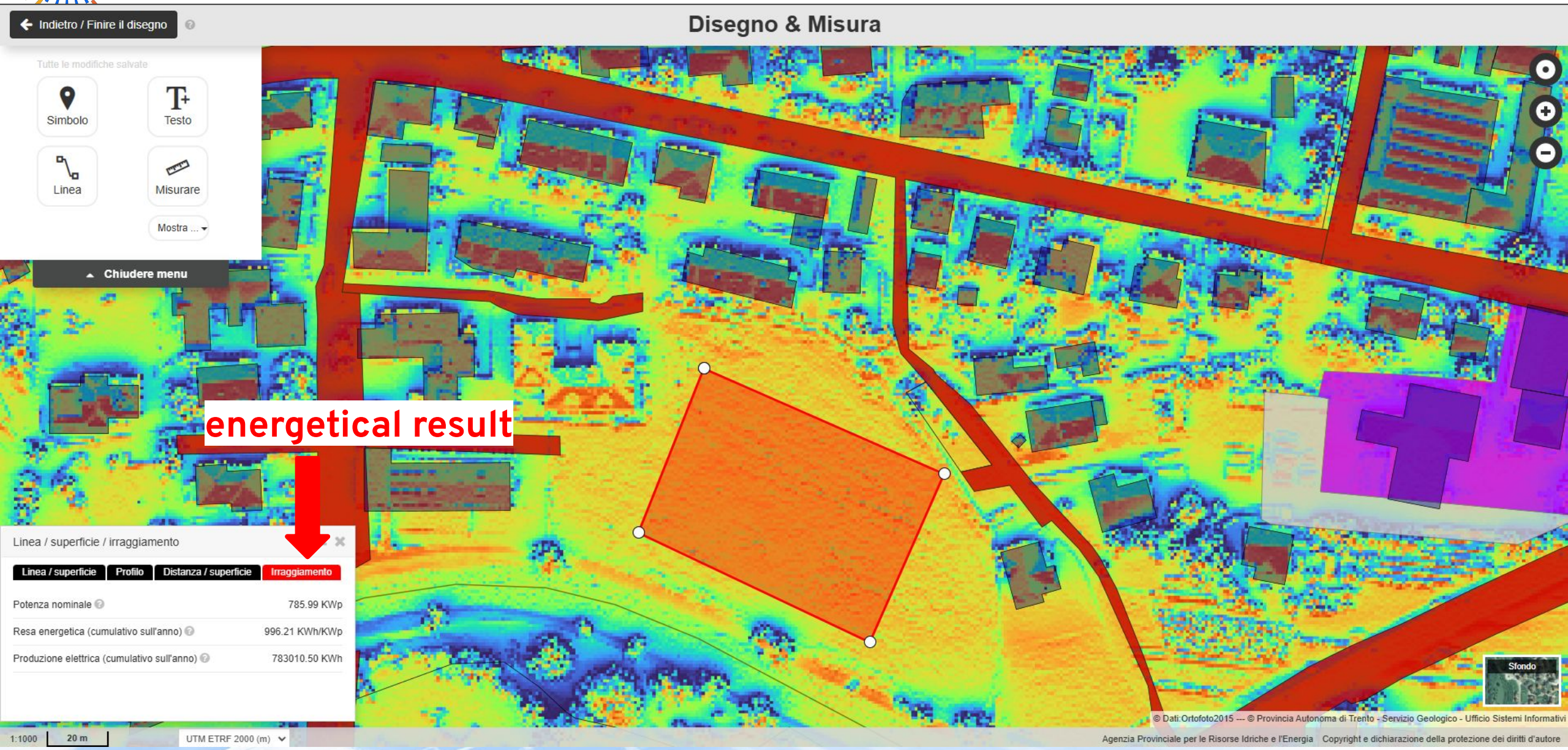

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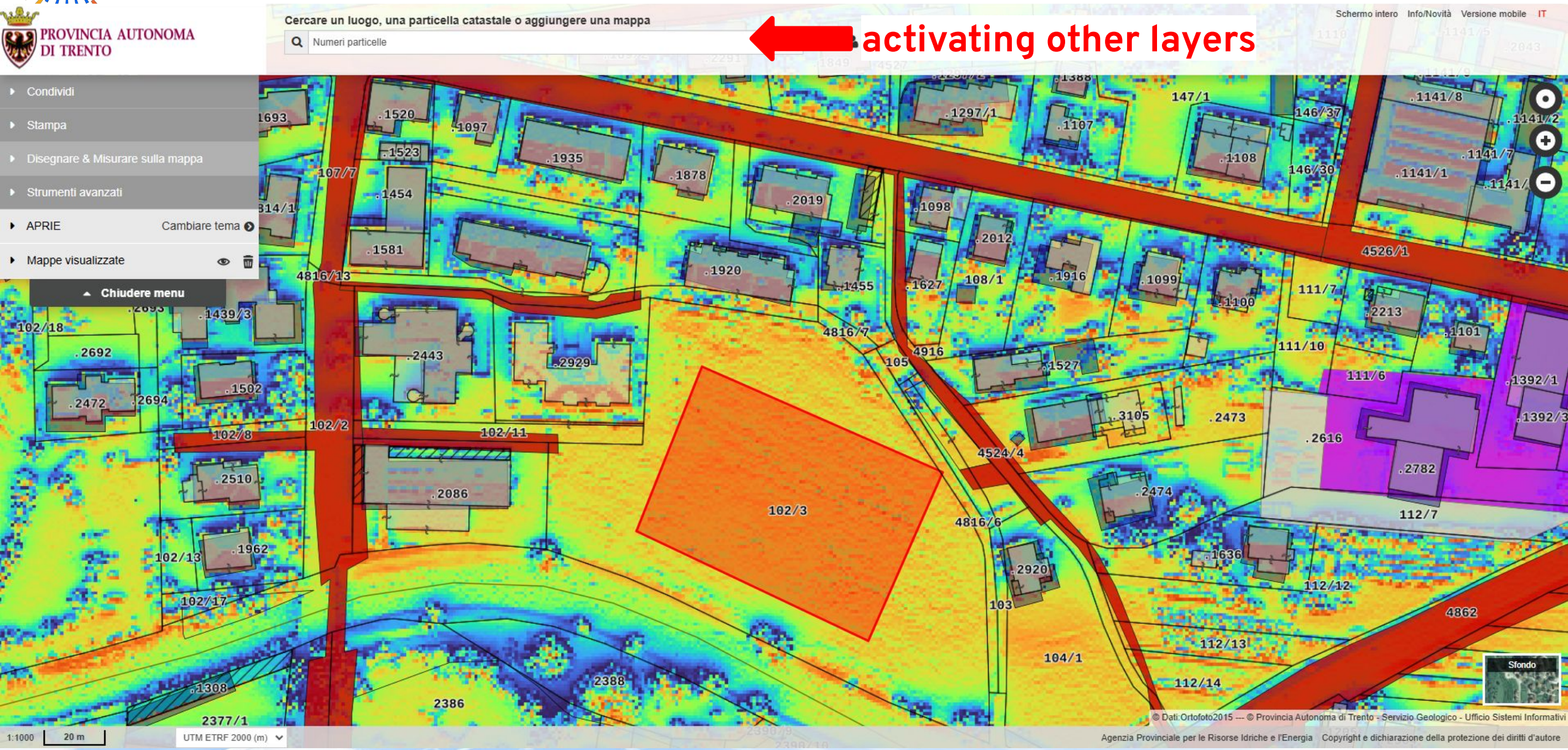

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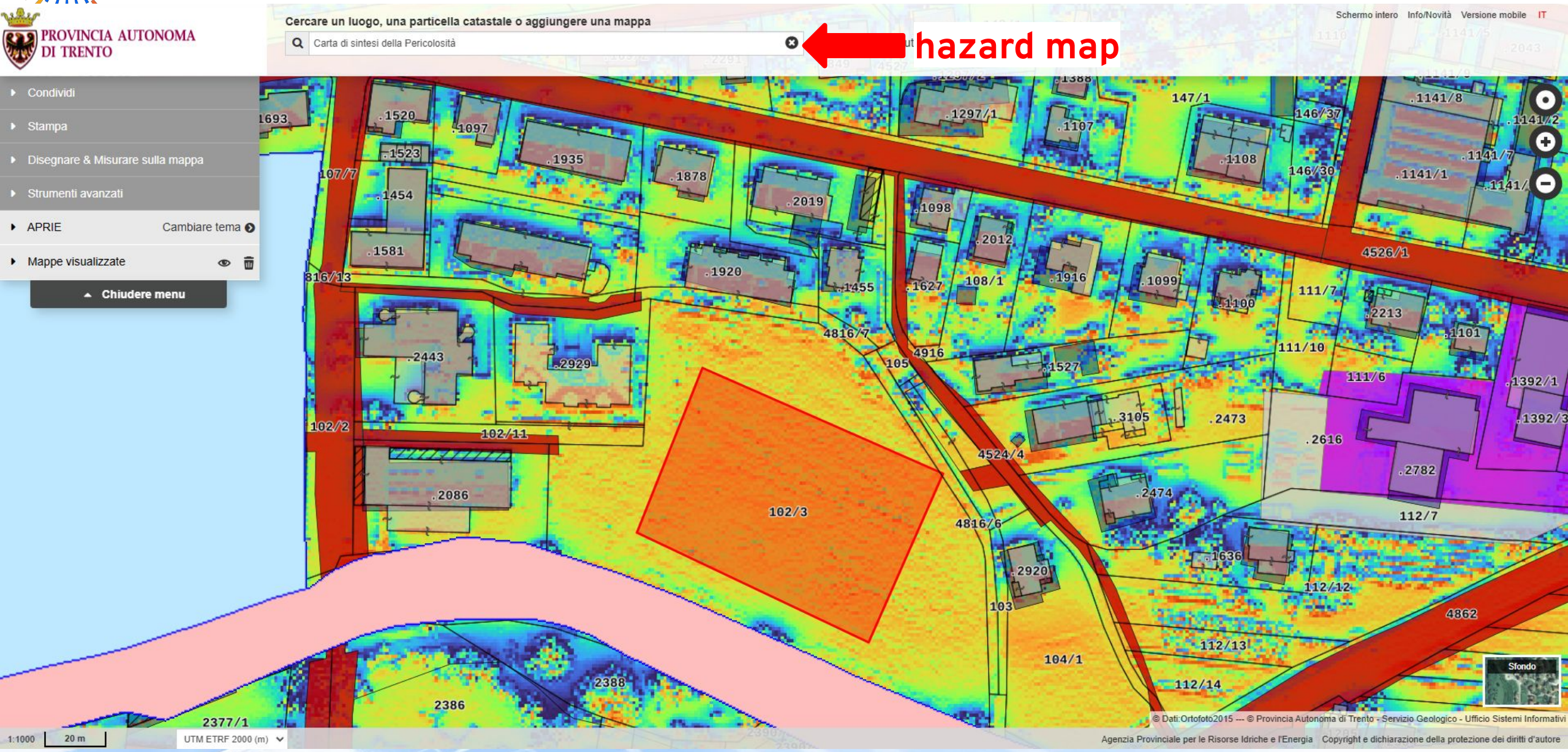

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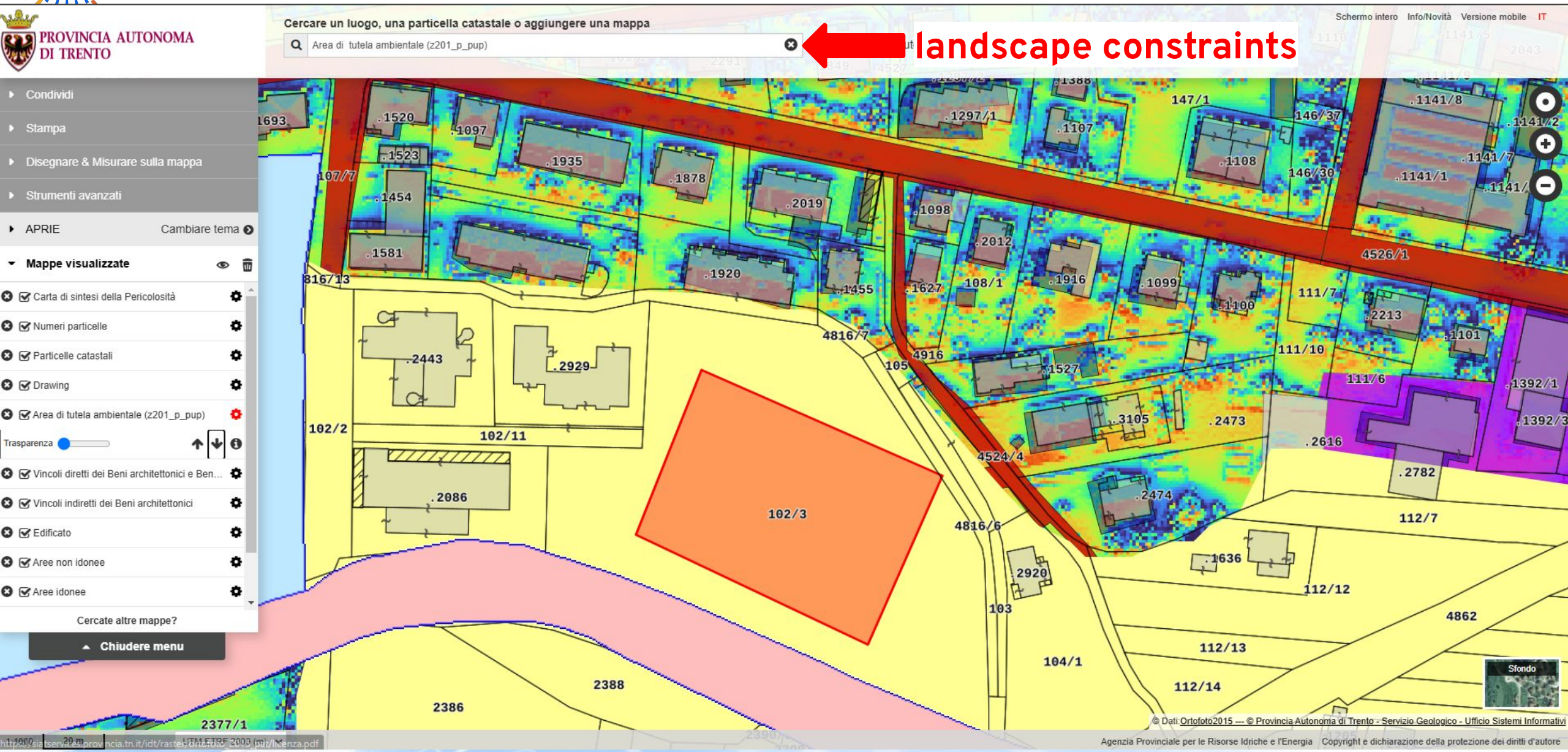

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CONCLUSIONS

Even considering some simplifications, the **Province of Trento (with the areas and suitable areas already identified with a theoretical 9.5 GW of power) proved to fulfill the energy production requirements from renewable sources,** presumably meeting the objectives of the PNIEC without the need to add further areas.

Making the results of this **unique analysis in Italy available in the public webgis** helps:

- **citizens** to identify the potential production of their building stock;
- **technicians** to compare irradiation values, to support the planning and the identification of constraints for the installation of solar energy systems;
- the **municipalities** to support the development of punctual energy policies;
- the **provincial services** that, through overlapping layers, can immediately identify areas subject to Integrated Energy Authorisation

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Thank you!

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