Multispectral satellite images to support the CIM (City Information Modeling) implementation

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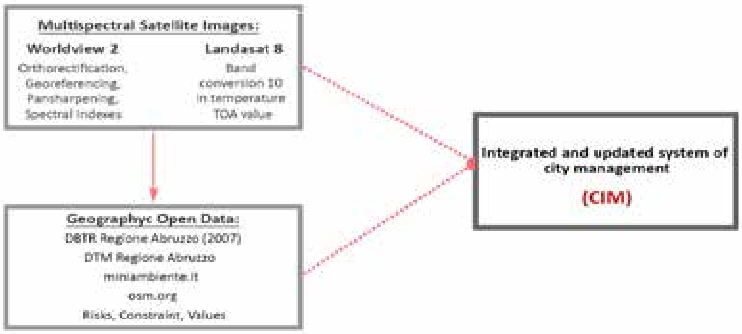

Fig. 1 - Workflow of the methodology.

This work shows the processing of additional information using high and medium-resolution multispectral satellite images. The new information obtained from specific spectral indices will converge with the data obtained from official sources in a single database, thus constituting a real parametric model of the city under study.

The "Smart City" is the new frontier for the management of the cities. It is a multidisciplinary concept that involves many actors and sciences. One of the topics related to the Smart City includes the development of new tools for the management of the city, especially for the urban planning management. Two new themes are involved in this process, the knowledge of the territory and the new technologies with the relative practices. (Di Ludovico D. et al., 2019)

About the knowledge of the territory, in these last decades, the geomatic techniques have covered a primary role in the heritage and city knowledge and management. Geomatic may be considered as a discipline devoted to the knowledge, measurement, monitoring and "Smart" management of the territory and consequently its structures and infrastructures. New tools have been developed in the last decades including laser scanning, UAV based-imaging, spherical and infrared images, mobile mapping systems, remote sensing that help to create georeferenced and certified metric 3D models and qualitative information about the territory. Geomatic results are very useful to create digital database in which converge several information useful to create an integrated digital system management of the city. In addition, with the development of Geographic Information System (GIS), the concept of the digital city is implemented widely. Today, for the urban planning, a new concept of city information modelling (CIM) is proposed to bring great benefits to urban construction and city management (Xun Xu et al., 2014). CIM is a BIM analogy in urbanism. In literature, it was also conceived as a 3D expansion of GIS (3DIS or 3D information system) enriched with multilevel and multiscale views, a designer toolbox and an inventory of 3D elements with their relationships. (Stojanovski 2013).

This work aims at experimenting with innovative methodologies to broaden and enrich the theoretical and applicative panorama of contemporary research in the field of urban planning and in particular in the CIM construction, considering fundamental the usage of the geomatic as primary knowledge of the territory. In particular, the usage of multispectral image processing in support of a specific territory helps to monitor and represent new levels of information and knowledge that can enrich and update the actual by being integrated into pre-existing ones.

In this paper, a case study of the use of remote sensing multispectral images is presented in order to extract information and "new levels of knowledge" with the purpose to enrich and update official source data layers, which will be used to realise an integrated CIM system for the management of urban planning.

The study area consists of a large part of the city of L'Aquila and some neighbouring hamlets, a territory hits by the tragic seismic event of 2009, which makes it a case study in continuous transformation.

Methodology

The study concern the use of multispectral satellite images to extract information to integrate the existing layers from official Geoportals to construct a CIM model for the smart management of the city. We will therefore start from the usage of remote sensing multispectral satellite images by exploiting the effective knowledge of the automatic (or semi-automatic) extraction of data relating to land cover and extracting detailed information on the studied areas. Fig. 1 shows the workflow followed to the final realisation of the CIM. Starting from the elaboration and the analysis of the multispectral images, new information are extracted and added in a 3D parametric model.

The official source data layers used are i.e.: DBTR (Regional Territorial Database) at scale of 1:5,000. Geographic information was organized into hierarchical groups. The hierarchical categories (each articulated into layers, themes, classes) are as follows: geodetic information; roads, mobility and transportation; real estate and anthropization; hydrography, orography; vegetation; technological networks; administrative limits etc.

Observing the workflow (Fig. 1), the input data are the geographic open-data "DBTR", dated before the 2009 seismic event and therefore to be updated. For this reason, the retrieval

Fig. 2 - Vegetation Spectral Index.

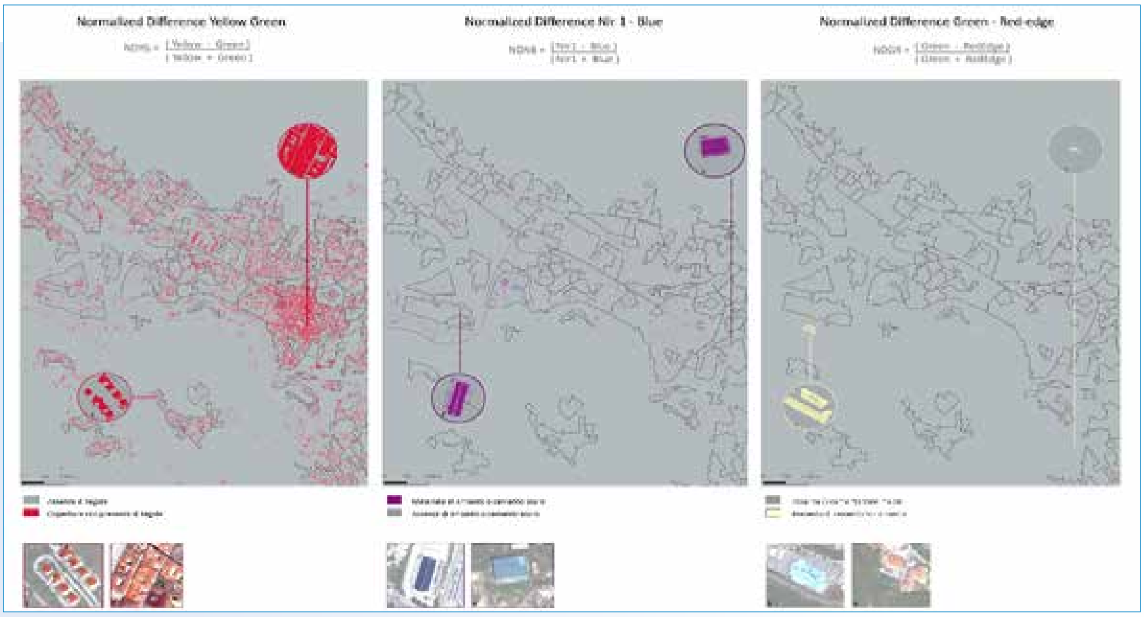

Fig. 3 - Built Spectral Indices.

of new information, especially through the acquisition of spatial data with remote sensing techniques, has not only allowed the updating of the "Update data layer" in progress, but will flow together with other information within the CIM.

Input data and tools

To extract new informative layers, two different kinds of satellite images are used: Worldview2 and Landsat8.
Worldview 2 satellite acquires very high-resolution images in 8 spectral bands. It covers the spectral range from 400 nm to 1050 nm at spatial resolution of about 2 m and the panchromatic band (400-800 nm) at spatial resolution of 0.50 m (https://earth.esa.int/eogateway/missions/worldview-2).
Landsat 8 provides respectively panchromatic imagery at 15 m of high spatial resolution and multispectral imagery at 30 - 100 m. Two sensors acquire multispectral images: the OLI sensor (Operational Land Imager) acquires 9 bands in the visible, Near Infrared, and ShortWave InfraRed portions of the spectrum (at 30 m) and the Thermal Infrared Sensor acquire 2 bands (called TIRS band) at 30 m in the Thermal Infrared (https://www.usgs.gov/core-science-systems/nli/landsat/landsat-8).
Some pre-processing operations are performed before the extraction of information, i.e. such as georeferencing, orthorectification and pansharpening for the WV2 images and some conversions to extract temperature information for the Landsat 8 (Fig. 1).

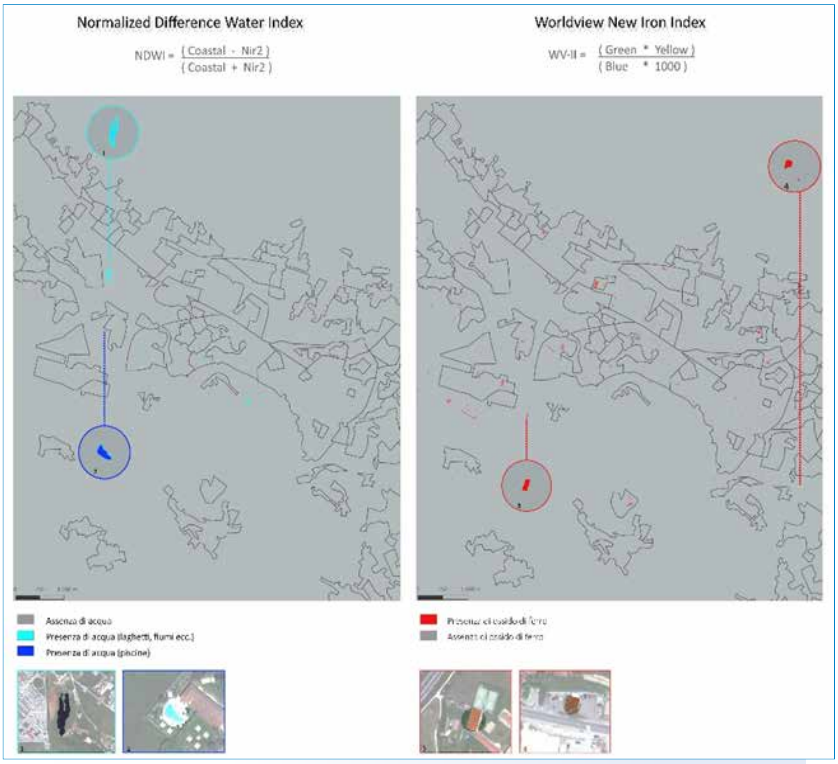

Fig. 4 - Further Spectral Indices.

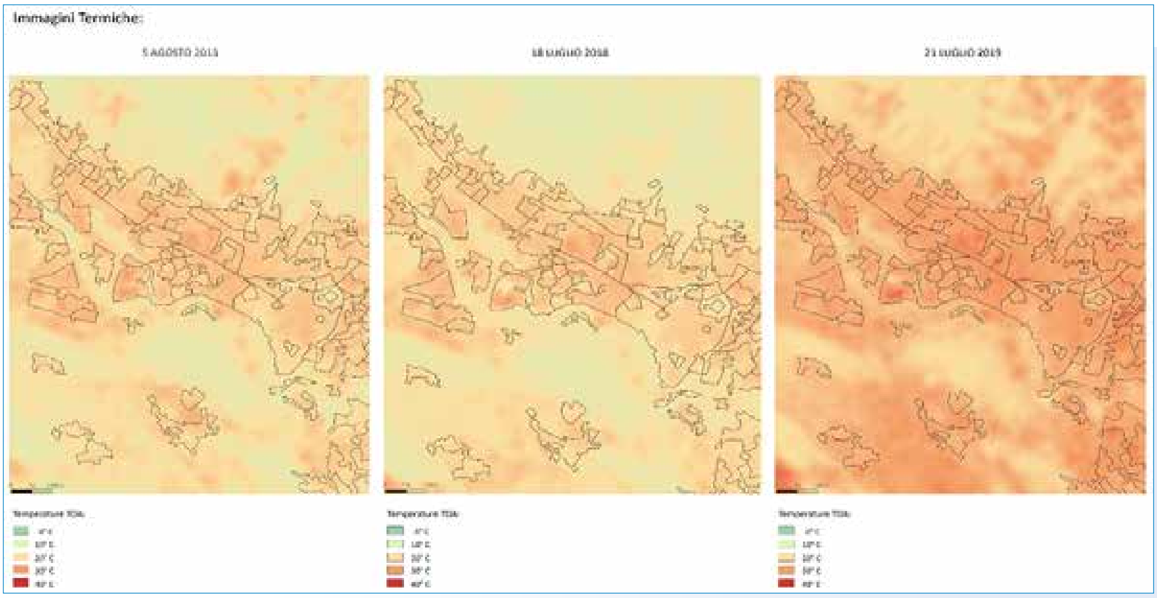

Fig. 5 - Temperature TOA.

WorldView 2 elaboration

Among the various approaches used to extract useful information from WV-2 images is the use of spectral indices. Indices are constructed by combining difference, sum and ratio (Dermais & Biagi, 2002). They are used to identify specific types of land cover, for example, and are especially useful for mapping urbanized areas. For our purpose, some indices are selected to extract information useful to the construct of the CIM to analyse and investigate.

One of the first results obtained concerns the thematic map related to vegetation, an in-depth index of which is reported (Fig.2):

Subsequently, it was possible to identify the different types of roofing mantles presented by the existing building, of which the related in-depth indices reported (Fig. 3 Built Spectral Indices):

- NDYG (Normalized Difference Yellow Green) uses the Yellow and Green bands in its formula. Useful for isolating roofing mantles from a tile material from the rest of the classes (Stamou et al., 2012);

- NDNB (Normalized Difference NIR1 and Blue) uses the NIR1 and Blue bands in its formula. Highlight the possible presence of asbestos (Hamedianfar A. et al. 2015);

- NDGR (Normalized Difference Green and Red Edge) uses the Green and Red-Eedge bands in its formula. Generated specifically to differentiate medium tone concrete roofs from dark concrete, asbestos, metal roofs and for road differentiation (Hashim N. et al. 2019).

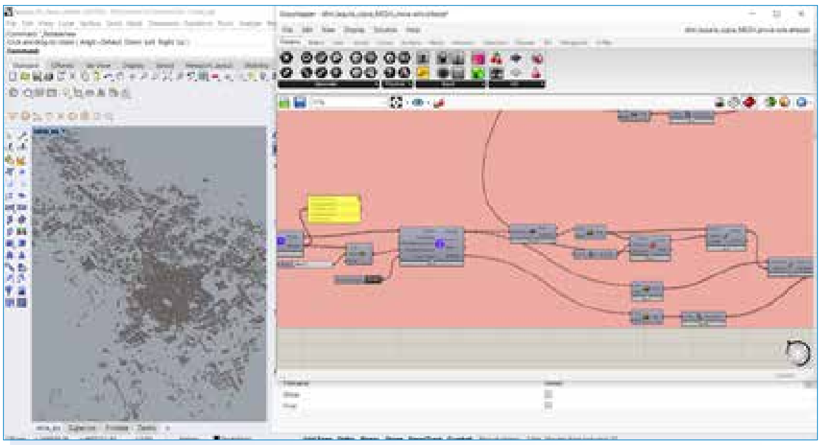

Fig. 6 - Overview of the model in Grasshopper, in yellow the associated attribute extracted from satellite images.

The last indices used are:

- NDWI (Normalized Difference Water Index) uses the Coastal and NIR2 bands in its formula. The Water Index takes into consideration the coastal band, which is useful for the study of areas characterized by water. (Wolf A., 2010). As shown in figure, the thematic map relating to this index has classified in absence of water and presence of water relating to

Fig. 7 - Overview of the model in Grasshopper, in yellow the associated attribute extracted from satellite images.

ponds, rivers and natural bodies of water and presence of water in anthropogenic elements such as swimming pools.

• WV-II (WorldView New Iron Index) uses the Green, Yellow and Blue bands in its formula.
Used to identify iron oxide rich pixels (Baptista G. et al. 2017).

Extraction of data from the thermal band
Nowadays, the thermal state of the urban environment is a reason of great interest for researchers, institutional bodies and for the citizens themselves. The knowledge of the energy exchanges of the urban surface is of primary importance for the study of urban climatology.
Synthetic thermal information can be acquired using Remote Sensing techniques, through sensors that operate in the thermal infrared (TIR) band.
To obtain a first valuation of the qualitative temperature of the area, three images were considered that could be obtained both directly from the site https://ers.cr.usgs.gov.
Three Landsat 8 images were chosen for comparison, acquired during the same summer period of several years, so that we could extract and highlight a first qualitative value of TOA (Top of Atmosphere) temperature values.
The images analysed are:

• An image from August 5, 2013, acquired at 09:49:12 AM
• A second image from July 18, 2018, acquired at 09:46:23 AM
• A last image from July 21, 2019, acquired at 09:47:10 AM

Landsat Collections Level-1 data can rescaled to top of atmosphere (TOA) reflectance and/or radiance using radiometric rescaling coefficients provided in the metadata file that is delivered with the Level-1 product. The metadata file also contains the thermal constants needed to convert thermal band data to TOA brightness temperature (Anderson I., 2016).

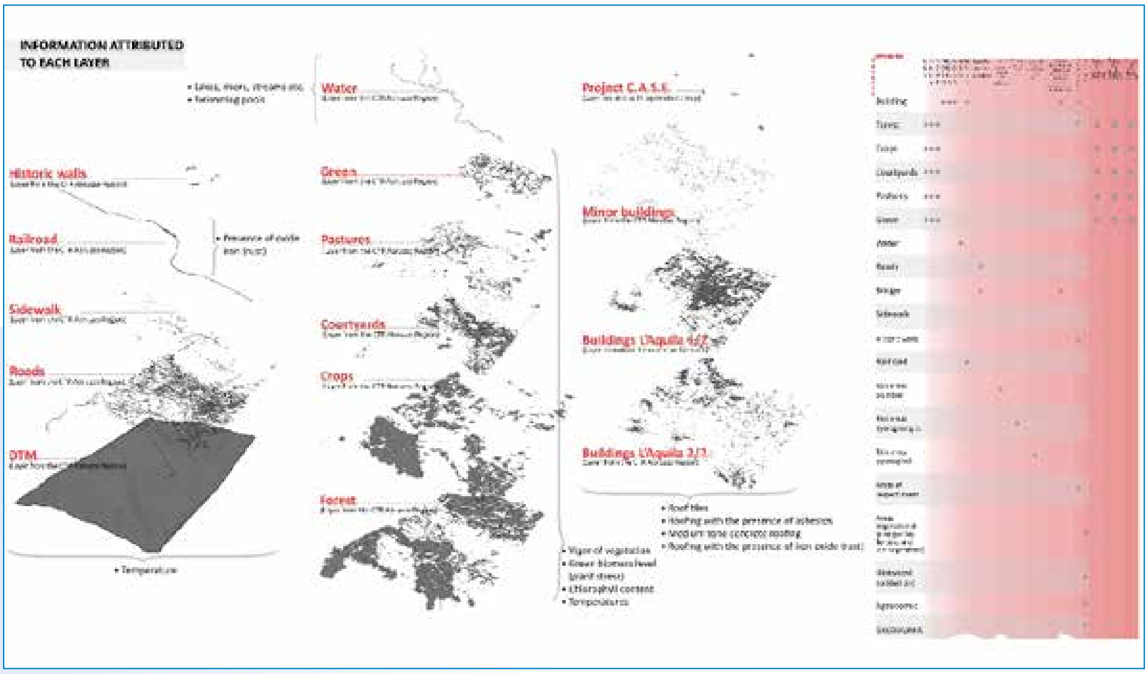

Fig. 8 - On the left the CIM layers and on the right the summary table with the added information.

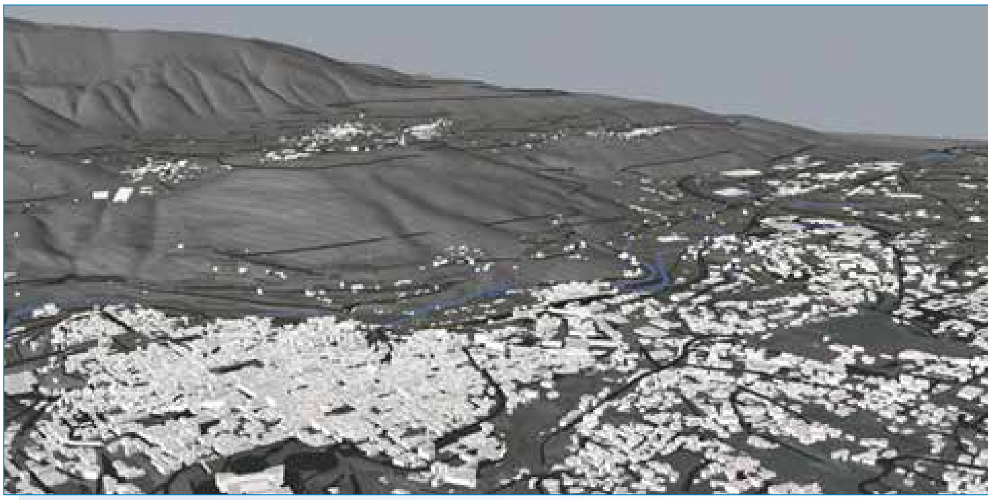

Fig. 7 - Overview of the model in Grasshopper, in yellow the associated attribute extracted from satellite images.

Construction and application of CIM

All the extracted information by the Multispectral images is added to Geographic open data, in order to obtain an updated basemap to construct the CIM. In addition, the Digital Elevation Model (made by interpolating the elevation data taken from the DBTR; the cell size is 10 meters per side and the reference system is UTM-WGS84) was used to create the surface reference system and to obtain the 3D model of the study area. Other data from official sources regarding the hydraulic, hydrogeological, pyrological risk and seismic microzonation of the territory and the analysis of the constraints and values present in the area under study, were analysed.

Next, all institutional information consulted and obtained was "linked" to the appropriate levels.

In detail, for our study area, the DBTR of the Abruzzo region was used and updated (available free of charge from the http://opendata.regione.abruzzo.it/ website). However, since this last file was dated before the 2009 earthquake that struck the city of L'Aquila, and therefore lacking all the new buildings and the most recent transformations that took place in the territory, it was integrated with the use of the following files:

- For the building, a shapefile downloaded from the site http://wms.pcn.minambiente.it, as it is more up-to-date than the DBTR;
- Finally, a new shapefile created specifically for missing buildings with the help of Osm (open street map).

Thus, all the data processed and described previously, will be implemented in GIS (Geographic Information System) software for creating a real 3D model of the city.

The data underlying this system are therefore GIS-like, georeferenced and associated with geometric primitives. For example, the shapefile format containing the amount of information from the analyses performed will describe the three-dimensional information model of the city, created with one or more digital visual scripting tools, creating a true parametric model of the city (CIM) formed by the integration of data from different systems.

The specific plugin used is Grasshopper, a visual programming and parametric modelling language that runs within Rhinoceros 3D's computer-aided design (CAD) application, which exports data from a GIS tool and imports it into a three-dimensional modeler, which allows to display all the information within.

The result will thus be an extended urban design model (CIM), to which different types of information can be associated.

The following figures show an overview of the 3D parametric model and respectively the geometrical features (Fig. 6) and qualitative attributes (Fig. 7) stored in the database. All the layers integrated in the model are shown in Fig. 8 e 9, in which a summary table of the added information coming from the satellite images is given.

Results and conclusion

This paper was produced for the purpose of presenting an innovative methodology in the field of experimentation, capable of creating cutting-edge models of future development.

It is evident that the satellite images used played an important role in finding more information to be included, along with the additional sources consulted, in our information model. In fact, the potential of remote sensing by means of high-resolution multispectral satellite imagery was found to be essential both for greater depth and knowledge of the area under study and for obtaining updated information in a short time. As a result, all of the various information found and converged within CIM will allow different aspects of the area to be monitored in the future.

For example, NDNB index relating to asbestos makes it possible to identify and then reclaim the areas that need it.

The use of TOA information can be useful for improving

the so-called heat island effect, which is increasingly prevalent within urban settlements. In fact, knowing the areas with the highest level of TOA, thanks to the introduction of greater coverage of the tree surface in deficient and identifiable areas thanks to the NDVI index, the effect of heat islands could improve.
Moreover, NDVI can be very useful for a first qualitative estimate of possible new buildings impervious surface present in the territory in real time, so DBTR's city is consequently updated.
In addition, by integrating different vegetation indices such as GNDVI (Green Normalized Difference Vegetation Index) and NDRE (Normalized Difference Red Edge), it is possible to derive more detailed information about the state of vegetation and obtain additional useful information for future developments.
Furthermore, NDWI is suitable for a possible update of DBTR with new body of water present, such as swimming pools, elements that can be useful in cases of fire, as reported in different studies.
An example to show how CIM system works was applied in dormitory fire case of Huazhong University of Science and Technology in Wuhan (Xun Xu et al., 2014). CIM system contains campus geographic location information, campus building information, the presence of water in the surrounding areas information, this information will have important role in fire emergency, reducing the times and bringing benefits. In fact, in the case study it reported how CIM is useful for reducing travel times and water supply in case of fire, gas leak, electrical short circuit and other events happened in the city. City information model (CIM) should include all aspects of city information, such as geographic information, buildings, infrastructure, property information, and so on. It can integrate a variety of disparate data sources by creating an integrated and interoperable in different data sets. (Xun Xu et al., 2014).
It's evident that CIM, with all its constantly updated information inside, is a real management model, useful for strategic urban planning. Although the CIM is still in its infancy and needs further study, it is clear that it will contribute to conceiving cutting-edge models for the future development of new digital technologies that take into account the dynamism and specificity of the territory and that will thus propose diversified solutions based on the starting data, aiming at the precise and punctual requests of the city and offering the possibility of following its evolution over time.

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PAROLE CHIAVE

Multispectral images; CIM; Thermal band; Spectral indexes; smart city.

ABSTRACT

This work shows the processing of additional information using high and medium-resolution multispectral satellite images. The new information obtained from specific spectral indices will converge with the data obtained from official sources in a single database, thus constituting a real parametric model of the city under study. An extended model of urban planning called "CIM" (City Information Modeling) will be developed, to which it is possible to associate information of different nature, which helps to monitor and manage the city.

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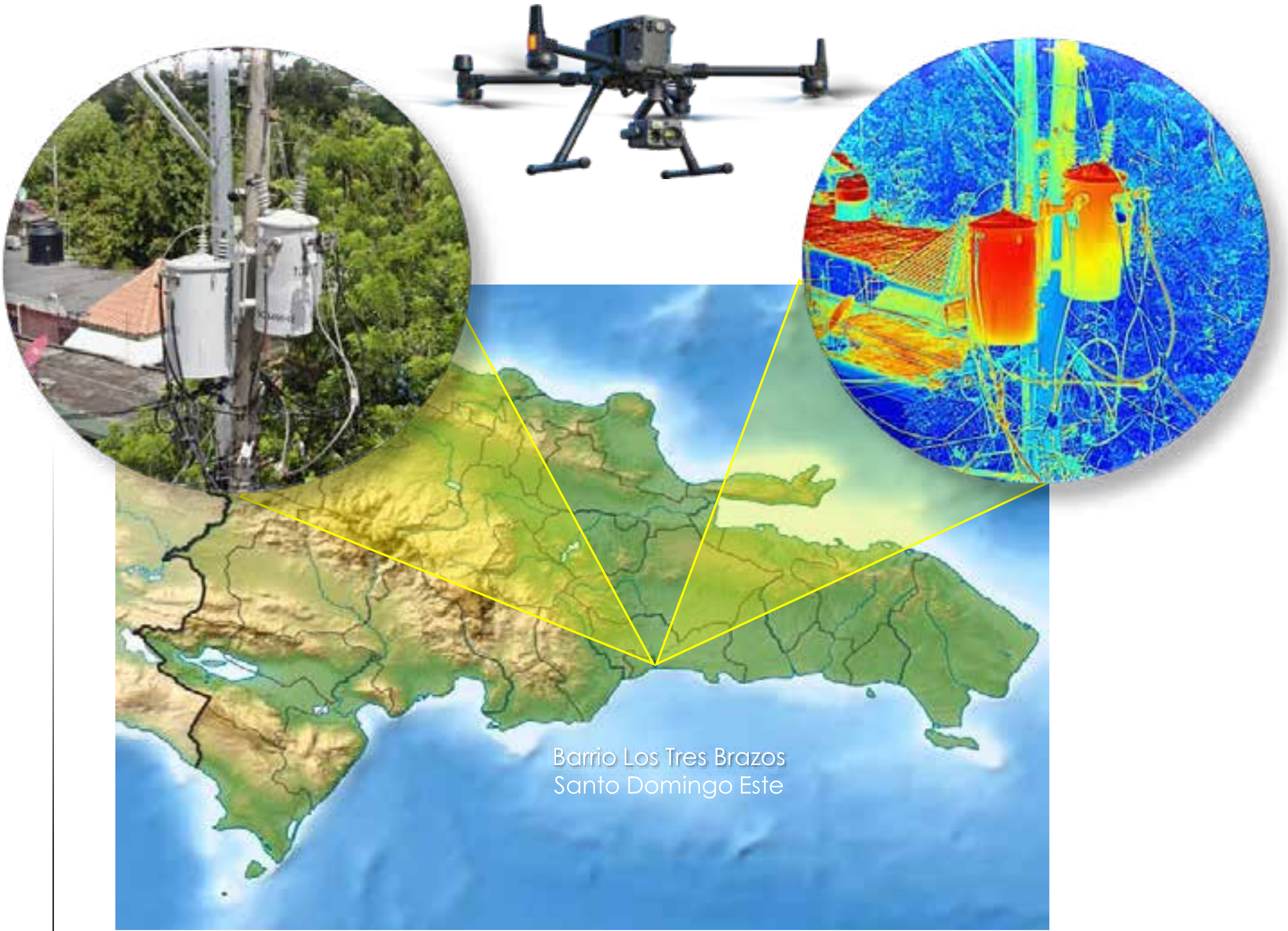
a GNSS-based integrated platform for energy decision makers



Asset Mapping Platform for Emerging CountRies Electrification

Despite global electrification rates are significantly progressing, the access to electricity in emerging countries is still far from being achieved. Indeed, the challenge facing such communities goes beyond the lack of infrastructure assets; what is needed is a holistic assessment of the energy demand and its expected growth over time, based on an accurate assessment of deployed resources and their maintenance status.

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