NEW DIGITAL SYSTEMS FOR THE MANAGEMENT OF CULTURAL LANDSCAPES

Author 1: Paola D'Antonio, Presidente del Corso di Laurea in Paesaggio Ambiente e Verde Urbano, Università degli studi della Basilicata, ITALY;
Author 2: Francesca Vera Romano, Università degli studi della Basilicata, ITALY
Author 3:Carmen D'Antonio, Università degli studi della Basilicata, ITALY
Author 4: Francesco Saverio Lopinto, Masseria Lopinto, Melfi ITALY
Author 5: Emilia Lacetra, Università degli studi della Basilicata, ITALY

1. Introduction

The research carried out concerned the relationships between the development of technologies and the history of Matera's cultural landscape. Key elements are the concepts of " cultural landscape " understood as a space in continuous construction that changes with the changing of the individual, collective, social and cultural relationships of the inhabitants of the territory, of "cultural inhabitant", that is a citizen producing culture more than a user, and vision of " future as an open place " in the sense of maximum usability and sharing of all human, material and immaterial productions through the use of technologies. In the light of the investigation it was found that Matera, a territory with a predominantly agricultural vocation, historically the site of *complex social relations, has created a traditional rural society in which the concept of neighborhood as well as a spatial connotation also had the symbolic connotation of sharing knowledge and practices, relationships, but most of the inclusivity and sustainability. The use of 5G technology, of which Matera is the site of experimentation, is generating important cultural transformations; what in the past was in Matera the neighborhood community, now becomes a virtual community, where the sharing of knowledge and practices, beliefs and values, including the use and management of cultural heritage, takes place through the network with the use of applications that promote accessibility and sustainability. For future scenarios it can be assumed, according to this historical anthropological forecast, that in technology, with its extreme pervasiveness, will facilitate an even easier access to historic sites and pa cultural heritage, in harmony with the preservation of cultural heritage and to encourage the dissemination of cultural content for one of their own wider fruition.*

Matera, as well as Basilicata and many Mediterranean areas has got a wide agricultural landscape which is deeply linked to its culture and inhabitants. So the focus of this research is also the employment of digital technologies for sustainable agriculture.

2. INNOVATION IN AGRICULTURE

In agricultural field it is necessary to link the increasing of production to sustainability and environmental protection policies – according to the protection of the natural heritage by reducing fertilizers, pesticides, fuel, as well as protecting forest resources from further tillage - without forgetting the *dangerous phenomenon of depopulation of rural areas and management criticalities resulting from sudden climate change. The strong spatial and temporal variability that characterizes any agro-ecosystem has determined the need to identify new tools and strategies to achieve an efficient and effective management of agricultural lands. To do this it is necessary to have techniques and technologies capable of detecting the lack of homogeneity and, later, of applying the cultural inputs within the plot in a variable way.*

The innovations connected to the world of agriculture so can be traced back to 3 fundamental themes

- *Information collection and management*
- *Analysis of information in a decision-making perspective*
- *Operations automation*

All of these fields can be better developed thanks to the most important technological trend of the moment, the 5G systems. They are born from the possibility of connecting objects and devices, even the most "unthinkable" ones. From sensors to monitor crop characteristics, to automatic guides, to drones useful for different purposes, from defense to land mapping.

With the technological endowment, available nowadays, the Internet of Things (IoT) realizes the connection between the physical objects, sensors and actuators and the connecting roads represented by the Internet.

So according to the continuous technological evolution, associated to the new EU and national regulations it has been developed a new management and business system: Precision Agriculture. So according to the continuous technological evolution, associated to the new EU and national regulations it has been developed a new management and business system that is object of experimentation in Matera: Precision Agriculture.

3. PRECISION AGRICULTURE IN MATERA: FIELD EXPERIMENTATION

In the most modern conformations, in perfect correspondence with the various emerging needs, the AdP is closely linked to geo-referencing systems, a process that allows you to permanently associate geographic coordinates with geometric-spatial information of various kinds and to new technologies as GIS, remote sensing and GPS.

Even modern agricultural machines are equipped with digital technology and are able to recognize the environment in which they operate.

Thanks to the monitoring by means of proximal and remote sensors, satellites, sensors on the machines, we are able to equip ourselves with software tools for storing geolocalized and vectored data, which allow us to have a spatial and punctual knowledge of the situation in the field.

The Variable rateo, for exemple, based on maps and sensors can manage the variability generated by the environment in which the cultivation takes place applying chemical, mechanical and biological inputs in a strategic and diversified *way combined to different methodologies with variable distribution (or variable rate).*

Today the use of drones (UAVS) is also gaining more and more space and importance in the field of agriculture at all stages of production. The drone is therefore a device capable of mechanizing every stage of cultivation, eliminating the cost of human error and helping to maximize earnings and return on investment. GIS technology is also a fundamental technology useful to characterize the specific environment of development of the plant and its vegetative state and it is the common denominator of other components related to geospatial technologies, such as remote sensing and GPS.

The GIS Technologies give us the opportunity to manage a considerable amount of data related to the territory by placing them in relation to each other in order to allow to detect phenomena that otherwise could not be highlighted.

WebGIS for exemple, is a platform that is also characterized by the use of Geographic Information System (GIS) but whose functionalities are based on network technologies (WEB/Internet).

The Environment for Visualizing Images (ENVI) software is used to process and analyze hyperspectral and/or infrared geospatial images. It is used for remote sensing and for analyzing images. ENVI brings together a series of scientific algorithms for image processing, many of which are contained in an automated wizard-based approach that guide users through complex tasks.

The use of different spectral acquisition bands can be employed to identify more the types of soil or in general the substance or chemical element of interest or to detect their characteristic spectral signature discriminating it from the others.

The use of different spectral acquisition bands can be employed to identify more the types of soil or in general the substance or chemical element of interest or to detect their characteristic spectral signature discriminating it from the others.

The fields of use of this software are varied. Here are some of them:

- *Vegetation classification and vegetative vigor of crops*
- *Classification of land use*
- *Crop nutritional and water stress monitoring*
- *Monitoring of weed infestation status*
- *Monitoring of the phytosanitary status of crops*

With the technological endowment, available nowadays, the Internet of Things (IoT) realizes the connection between the physical objects, sensors and actuators and the connecting roads represented by the Internet.

4. THE VARIABLE RATE

The variable application can be applied in all operations, starting from the tillage of the harvest, even if currently the machines that have developed faster are those related to the sowing and the mineral fertilizer.

With the same technological equipment it is also possible:

- *To carry out working of the soil ;*
- *To distribute agro-drugs;*
- *To carry out defoliation practices;*
- *To distribute in a localized way the zootechnical waste;*
- *To start the identification of pathologies and weeds In the field*

Computerized management of crops and livestock can lead to sensitive optimizations and productivity gains, also throwing the foundations for the full use of agri-robotics and drones.

A fundamental step in order to evaluate only the positive sides of this new agriculture is to work on the training of technicians for assistance. At the same time we must intervene on raising awareness of farms.

Another important innovative tool for agriculture is Block chain.

The blockchain (literally "block chain") is a shared, unchanging data structure a digital register whose entries are grouped in blocks, in chronological order, whose integrity is guaranteed by the use of encryption. It is similar to a distributed database, that is not centralized, managed by a network of nodes, each of which has a private copy. Therefore, due to these characteristics, it is considered an alternative in terms of security, reliability, transparency and costs to databases

The blockchain promotes transparency and visibility along the food chain. Cryptographic features on food source, quality, transit temperature and freshness can be used to ensure that data is real, accurate and truthful, instilling confidence and ensuring safety for both consumers and retailers.

Thanks to blockchain it is possible to obtain the traceability of a product in all the phases that characterize it from the raw material to the finished product.

Moreover a community recognizes itself within a landscape and the as IOT and Blockhain are tool for safeguard and enhancement not only of agricultural production, but also of *the broader territory through the promotion and knowledge of these productions as a synthesis of culture, traditions, processes, raw materials and biodiversity, a cultural landscape as a set of indigenous elements of a site, components of an identity path that the man has enriched with his contribution without altering the identity profiles. Technologies also help the community to be more linked to its territory helping people to be more conscious and more informed about their landscape and its history, so for their own culture.*

Figure 1: *Test in Matera based on prescription maps and 5G*

1 Introduction

Agricultural fields have been always considered as uniform entities and managed accordingly (Mulla, 2013). However, uniform agronomic management in fields where spatial variability is present, is economically and environmentally inefficient (Pierce and Nowak, 1999). In Mediterranean environments the benefit of managing the field in zones can only be achieved by dividing the fields in areas that are consistent in yield performance (Robertson et al., 2005; Ritchie et al., 2008).

Commonly, yield maps are acquired at harvesting and segmentation techniques are applied to delineate the Management Zones (MZ). Yield data have significant error sources, such as via sensor, georeferencing, operator or data processing errors (Simbahan et al. 2004), and are also complicated to prepare (Blackmore and Marshall 1996). Moreover, the irregular distribution of data points in regard to the spatial variation in yield can impede accurate interpolation, which is a necessity for most spatial analyses. The use of soil sampling data and soil maps for delineation of MZ is also a common approach, especially if yield maps are not available. Electrical resistivity tomography (ERT) maps can also be used for successful MZ delineation They reflect soil differences due to such factors as moisture content, salinity and texture. However, even if these characteristics influence crop growth significantly, ERT maps may not always give a direct picture of in-season vegetation patterns. In addition, ERT of soil is influenced by a number of complex and mostly inter-related parameters (Lück et al. 2009), therefore interpretation is not necessarily straightforward. Since spatial patterns in ERT measurements are affected by seasonal effects (e.g. weather conditions; Lück et al. 2009).

Satellite remote sensing provides spatial continuity and extent, spectral crop information and low cost. When analyzing time series, satellite remote sensing is often more cost-effective and offers an archive of already acquired data by operating sensors. When it comes to determining MZ on the basis of actual crop growth patterns, satellite imagery applications are valuable tools in precision farming (Basnyat et al. 2005).The major disadvantage of optical satellite imagery however is the dependence on a clear, cloud-free view. A considerable number of studies related to crop growth and yield(Hank et al. 2015; Lobell et al. 2015) are based on satellite images within one growing season (Song et al. 2009). However, Thenkabail (2003) pointed out the potential of multi-temporal analysis of archived remote sensing data in combination with real-time data.

The delineation of zones based on remotely sensed images confirms large differences in canopy growth that lead to yield variability (Basso et al., 2007). Such images taken during key growing stages might help to characterize the spatial variability of crops and delineate areas with similar response. Robertson et al. (2007) using spatial information from remote sensing and soil attributes at whole-farm and catchment scale showed the presence of spatial patterns of soillandscape useful to identify areas with both low productivity and excessive nitrate leaching.

The objective was the delineation of a field homogeneous zones based only on satellite data. In the optics of remote sensing open data (Copernicus and Landsat missions) of earth observation, an automatic segmentation algorithm, for within-field crop patterns delineation, was developed by using only multi-temporal and multi-spectral satellite images. Yield maps, rainfall and topographic data were used to characterize and validate the spatially and temporally stable areas. This study makes it possible to attribute the correct nitrogen fertilization rate to each zone.

2 Materials and methods

2.1. Site description and agronomic management

The studied carried out by C. Fiorentino, A.R. Donvito, P. D'Antonio and S. Lopinto on a 18 ha field located in Melfi, Potenza-Italy during six years of alternate cultivation of wheat and forage showed that he spatial variability of soil properties and the distribution of the rainfall influenced both the spatial and temporal variability of grain yield. The analysis allowed the identification of two spatial and temporal stable zones and one unstable zone (figure 2a). High level of clay in soil has an important implication in terms of water stored into the* *soil during the fallow period or growing season, and in terms of rooting depth. The crop response to rainfall is the result of dynamic interaction of spatial static properties (soil texture, position in the landscape) and dynamic properties (soil water content, infiltration and crop water use).In Mediterranean environment, wheat yield is influenced by rainfall and amount of water stored in the soil before the growing season and soil water availability during the growing season(Basso et al., 2012). Wheat yield response to stored soil water varies according to the site and the soil type (Anderson, 2010).The balance between fallow rain and growing season rainfall plays an important role in determining grain yield. The amount of rain stored in the short fallow period (September–November) was an important factor affecting the spatial and temporal variability of wheat yield. Sadras et al. (2012) have demonstrated that there are no beneficial effects of the long fallows water storage and concluded that the benefits of fallow rainfall declined with the increase of seasonal rainfall. Crops that rely on fallow rainfall lose much less in soil evaporation during the growing season, although evaporative losses before sowing could be significant (Hatfield et al., 2001). Once the homogeneous areas were identified (by processing the data from 2013/14 to 2017/18 growing season), a correlation analysis was carried out between mean estimated yield and rainfall for each zone. The total rainfall was divided into fallow and growing season rainfall. The fallow rainfall was sub-divided in two periods, long fallow (June–November), and short fallow (September–November). Growing season rainfall (December–May) was sub-divided into vegetative rainfall (December–February) that corresponds to the rainfall period from sowing to end of tillering, and reproductive rainfall (March–May) that is the* *rainfall period between stem elongation and maturation. Growing season rainfall and fallow rainfall from 2013 to 2019 were reported in Table1.These rainfall periods were correlated to grain yield of each zone through the Pearson’s coefficients.This analysis showed a significant, negative correlation between estimate average yield and vegetative growing season rainfall. The negative correlation was higher for the HS zone. This was probably due to the clayey soil component and the lower altitude of the HS zone (fig 2b). By removing from the analysis, the growing seasons with the highest level of short fallow rainfall (Table1: 2018/19, 1016/17 and 2014/15) the correlation between average yield and short fallow rainfall per zone became significant.*

The correlation analysis between average estimated yield per zone and TWI index (figure 2b)showed a significant positive correlation of HS zone with TWI for all study years, it was very low only in 2014/15 growing season. The Pearson correlation coefficient was higher than the others during the most productive growing season (2015/16) reaching the value of 0.63. The 2015/16 growing season was the driest during vegetative growing season.The lowest value of the Pearson correlation coefficient was reached for the 2013/14 growing season (0.32). it was the wettest during vegetative growing season.

Kaspar et al. (2003) related six years of corn yield data with soil attributes. They found that in four years, where rainfall was lower than the average, corn yield showed negative correlations with elevation, slope and soil curvature, and in the two years with abundant rainfall, the yield was positively *correlated with those parameters. Kravchenko et al. (2005) found that the coefficient of variation increased in years with low rainfall (45%) and decreased in years with high rainfall (14%). Therefore, the effect of weather patterns on both crop growth and development and its interaction with soil type causes bias in the assessment of homogeneous management zones (Basso et al., 2009).*

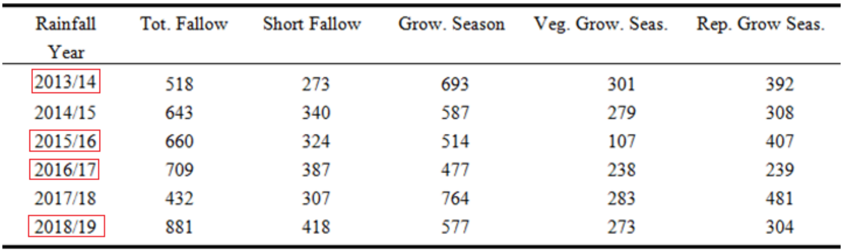
Adequate rainfall before sowing provides proper condition for good seed germination and enough supply of water for later growth. all of them (Van Herwaarden et al., 1998; Angus and van Herwaarden, 2001; Basso et al., 2011a,b).

In figure 3a, the yield map of 2018/19 growing seasonwas reported, it was used to validate the methodology proposed in this work. In figure 3b, c and d it was shown the NDVI index for growing season 2018/19 at different dates, from the end of March to the end of April. It is possible to observe the very similar pattern of NDVI maps and yield, despite the different spatial resolution.

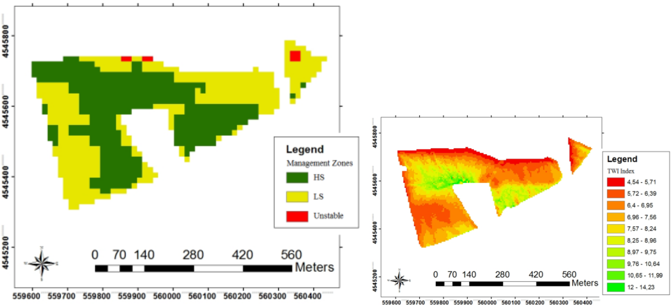
*In figure 4a the graph of mean NDVI values for HS and LS zone for each study year was shown. The HS zone always produces more than the LS. The higher values of grain yield from 2015/16 growing season are probably due to the pre-sowing digestate application.
it is interesting to note the very low average NDVI value associated with the LS zone in the year 2016/17, while the HS zone maintains an average NDVI value comparable with that*

of the following years. During this year the rain in March and April was the lowest compared to the others studied years:71 mm in April with a single event of 36 mm and 82 mm in April with 2 events exceeding 15 mm of rain. Probably due to the slope this area has suffered from the lack of rain. In the graph, in figure 4b, the average field yield vs average NDVI was reported. The average yield estimated for 2018/2019 growing season was about 61.4 Q ha−1with the HS zone which produces about 10% more than the LS. The measured average value of grain yield in 2019 was about 61.8 Q ha−1.

Table 1. Mean growing season rainfall and fallow rainfall (mm) from 2013 to 2019.In the years highlighted in red wheat crop was seeded.

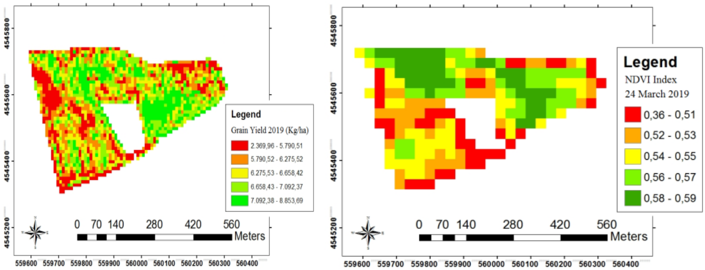


Rainfall Year	Tot. Fallow	Short Fallow	Grow. Season	Veg. Grow. Seas.	Rep. Grow Seas.
2013/14	518	273	693	301	392
2014/15	643	340	587	279	308
2015/16	660	324	514	107	407
2016/17	709	387	477	238	239
2017/18	432	307	764	283	481
2018/19	881	418	577	273	304

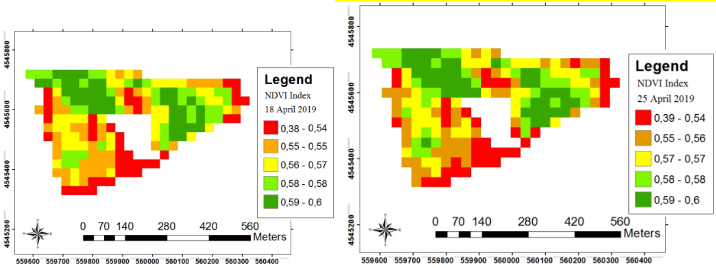


(a) *(b)*

Figure2.(a) Management zone map, in green is reported the high yield and time stable zone, while in yellow is shown the Low yield and time-stable zone . (b) TWI index elaborated from the digital terrain model.



(a) *(b)*



(c) *(d)*

Figure3.In figure a is shown the 2019 grain yield map. In figures b, c and d are shown the NDVI indices acquired during 2019 growing season from Landsat8 satellite on: 24 of March, 18 and 25 of April.

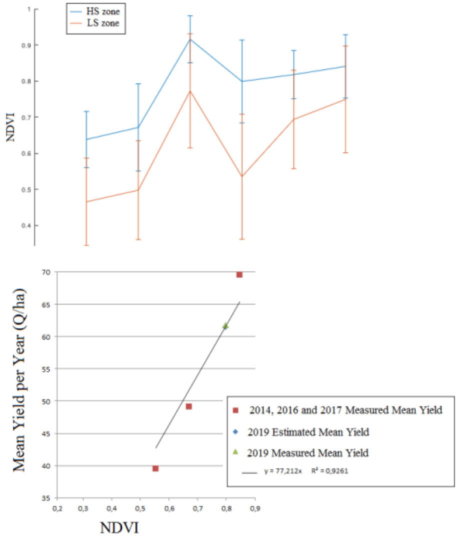


Figure4.The graph of mean NDVI values for each study year and for both, HS and LS zone, is reported in figure a. Figure b shows, in red, the mean field NDVI vs measured average grain yield for 2014, 2016 and 2017 growing seasons. In the graph the measured and the estimated average grain yield are also reported.

5. CONCLUSIONS

Matera, is a virtuous example of the successful interaction between tradition and innovation because it is a city that held the primacy for the agricultural tradition and that is now preserved, lives, through the technological innovation in agriculture.

Matera is a city that held the primacy for the agricultural tradition and that is now preserved, lives, through the technological innovation in agriculture.

In Matera with the 5G what was the agricultural neighborhood in the years'50 now becomes digital neighborhood. Thereby, for future scenarios it can be assumed, according to this historical anthropological forecast, that technology, with its extreme pervasiveness, will facilitate the sharing of knowledge and practices, beliefs and values and actions, included safeguard and awareness on the agricultural landscape, can now be managed through the network and so promoting innovation and sustainability of production.

6. REFERENCES

1. Andersen, A., Persavento, U., and Wang, Z. J. (2005). *Unsteady Aerodynamics of Fluttering and Tumbling Plates. Journal of Fluid Mechanics* 541, 65–90.
2. Anderson, W.K., 2010. *Closing the gap between actual and potential yield of rain-fed wheat. The impacts of environment, management and cultivar. Field Crop Research 116, 14–22.*
3. Baldwin, B. S., and Lomax, H. (1978). Thin Layer Approximation and Algebraic Model for Separated Turbulent Flows. 16th AIAA Aerospace Sciences Meeting, Jan. 16-18, Huntsville, Ala.

4. *Basnyat, P., McConkey, B., Selles, F., &Meinert, L. (2005). Effectiveness of using vegetation index to delineate zones of different soil and crop grain production characteristics. Canadian Journal of Soil Science, 85(2), 319–328.*

5. *Basso B., Fiorentino C., Cammarano D., Cafiero G., Dardanelli J.. (2012) Analysis of rainfall distribution on spatial and temporal patterns of wheat yield in Mediterranean environment. Europ. J. Agronomy 41 pp. 52– 65.*

6. *Basso, B., Bertocco, M., Sartori, L., Martin, E.C., 2007. Analysing the effects of cli-mate variability on spatial pattern of yield in a maize–wheat–soybean rotation. European J. of Agronomy 26, 82–91.*

7. *Bendat, J.S., and Piersol, A.G. (2000). Random Data: Analysis and Measurement Procedures. Third edn. John Wiley & Sons, Ltd.*

8. *Blackmore, B. S., & Marshall, C. J. (1996). Yield mapping; errors and algorithms. In P. C. Robert, et al. (Eds.), Precision Agriculture: Proceedings of the 3rd International Conference (pp. 403–416). Madison, WI, USA: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America (ACSESS publications).*

9. *Blackmore, B.S., 2000. The interpretation of trends from multiple yield maps. Computers and Electronics in Agriculture 26, 37–51.*

10. *Blackmore, S., Godwin, R.J., Fountas, S., 2003. The analysis of spatial and temporal trends in yield map*

data over six years. Biosystems Engineering 84, 455–466.

11. Boydell, B., &McBratney, A. B. (1999). Identifying potential within-field management zones from cotton-yield estimates. Precision Agriculture, 3(1), 9–23. https://doi.org/10.1023/A:1013318002609.

12. Brisco, B., Brown, R., Hirose, J., McNairn, H. and Staenz, K. (n.d.). *Precision Agriculture and the Role of Remote Sensing: A Review.* Retrieved on 1st October 2012.
13. Esri (2008). GIS for Sustainable Agriculture. GIS Best Practices. New York: ESRI Publications.
14. Sohne, W., Heinze, O. and Groten, E. (1994). Integrated INS/GPS System for High Precision Navigation Applications. *Record-IEEE PLANS, Position Location and Navigation Symposium,* 35(2): 310-313.
15. Xiangjian, M. and Gang, L. (2007). Integrating GIS and GPS to Realise Autonomous Navigation of Farm Machinery. New Zealand Journal of Research, 50(1), 807-812.
16. E. Chiodo, E. Liberatoscioli, C. Salvioni *Le informazioni territoriali e la geomatica per l'agricoltura e lo sviluppo rurale* Agriregionieuropa anno 4 n°14, Set 2018
17. A. Cecchini, A. Plaisant, F. Angeli – *Analisi e modelli per la pianificazione Teoria e pratica: lo stato dell’arte* 2005 Facoltà di Architettura di Alghero.
18. M. Onorato, F. Fantola, P. Schirru, S. Urru, D. Pili - *Il webgis strumento per l'assistenza tecnica nell'agricoltura sostenibile* ASITA 2016.

19. F. Kuhn, B. Horig - *Environmental remote sensing for military exercise places. Remote Sensing and GIG for Site Characterizations: Applications and Standards, ASTM STP 1279, American Society for Testing and Materials 1996.*
20. A. Calcante – *L'automazione nelle macchine agricole* Dipartimento di scienze agrarie e ambientali Milano.
21. *Sistemi di guida in agricoltura; Tecnologia a Rateo Variabile* – Progetto AGRICARE Aprile 2017.
22. R. Casa – *L'applicazione dell'agricoltura di precisione per il miglioramento della gestione delle produzioni vegetali* Dipartimento di scienze Agrarie e Forestali, Università degli Studi della Tuscia Viterbo 2017

23. Hank, T., Bach, H., & Mauser, W. (2015). Using a remote sensing-supported hydro-agroecological model for field-scale simulation of heterogeneous crop growth and yield: Application for wheat in Central Europe. Remote Sensing, 7(4), 3934–3965. https://doi.org/10.3390/rs70403934.

24. Lobell, D. B., Thau, D., Seifert, C., Engle, E., & Little, B. (2015). A scalable satellite-based crop yield mapper. Remote Sensing of Environment, 164, 324–333. https://doi.org/10.1016/j.rse.2015.04.021.

25. Lück, E., Gebbers, R., Ruehlmann, J., & Spangenberg, U. (2009). Electrical conductivity mapping for precision farming. Near Surface Geophysics, 7(32), 15–25. https://doi.org/10.3997/1873-0604.2008031.

26. *Impiego delle tecnologie satellitari e 5G nella conoscenza e gestione dei paesaggi culturali: il caso*

di studio di Matera, Capitale della Cultura Europea 2019, F. V. Romano, F. Toscano, N. De Iorio, C. D'Antonio, InV:ito alla Storia, Terza Conferenza Nazionale dell'Associazione Italiana di Public History #AIPH2019, Università degli Studi della Campania Luigi Vanvitelli, Santa Maria Capua Vetere, 24-28 giugno 2019.

27. MATERA e Pompei: TECNOLOGIE E SOSTENIBILITÀ DEI DUE PAESAGGI STORICI. C. D'Antonio, F. V. Romano, InV:ito alla Storia, Terza Conferenza Nazionale dell'Associazione Italiana di Public History #AIPH2019, Università degli Studi della Campania Luigi Vanvitelli, Santa Maria Capua Vetere, 24-28 giugno 2019.
28. META MATERA SASSI TOWARDS, Prefazione, M. Vanore,. Anteferma Edizioni, Giugno 2019 Venezia, ISBN: 978-88-32050-32-5

29. Robertson, M., Isbister, M., Maling, I., Oliver, Y., Wong, M., Adams, M., Bowden, B., Tozer, P., 2007. Opportunities and constraints for managing within-field spatial variability in Western Australian grain production. Field Crops Research 104, 60–67.

30. Ritchie, J.T., Basso, B., 2008. Water use efficiency is not constant when crop water supply is adequate or fixed: the role of agronomic management. European J. of Agronomy 28, 273–281.

31. Robertson, M., Isbister, B., Maling, I., Oliver, Y., Wong, M., Adams, M., Bowden, B., Tozer, P., 2005. Managing spatial and seasonal variability within field can improve the profitability of WA grain production.

In: Turner, N., Acuna, T. (Eds.), Groundbreaking Stuff. Proceedings of the 13th Australian Agronomy Confer-ence. 10–14 September 2006 Perth, Western Australia.

32. *Rouse, J.W., Haas, R.H., Schell, J.A., Deering, D.W., 1974. Monitoring vegetation systems in the Great Plains with ERTS. In: Third ERTS Symp., NASA SP-351 1, pp. 309–317.*

33. *Sakamoto, T., Gitelson, A. A., &Arkebauer, T. J. (2013). MODIS-based corn grain yield estimation model incorporating crop phenology information. Remote Sensing of Environment, 131,215–231. https://doi.org/10.1016/j.rse.2012.12.017.*

34. *Sørensen, R.; Zinko, U.; Seibert, J. (2006). "On the calculation of the topographic wetness index: evaluation of different methods based on field observations". Hydrology and Earth System Sciences. 10: 101–112.*

35. *Simbahan, G., Dobermann, A., & Ping, J. (2004). Site-specific management—Screening yield monitor data improves grain yield maps. Agronomy Journal, 96(4), 1091–1102.*

36. *Song, X., Wang, J., Huang, W., Liu, L., Yan, G., & Pu, R. (2009). The delineation of agricultural management zones with high resolution remotely sensed data. Precision Agriculture, 10(6), 471–487. https://doi.org/10.1007/s11119-009-9108-2.*

37. *Thenkabail, P. S. (2003). Biophysical and yield information for precision farming from near-real-time and historical Landsat TM images. International Journal of Remote Sensing, 24(14), 2879–2904. https://doi.org/10.1080/01431160710155974.*