Propensity to Use an Aerial Data Collection Device in Agricultural Research

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Abstract. The access to information as a success factor in areas of human activity gains relevance with the intensive adoption of ICT. An important sector such as agriculture cannot be left out of this phenomenon. The results obtained in agricultural research show an increasing dependence on the intensive use of data, with a bigger volume and variety, origin in different environments, and through different technologies. The objective of this study is to categorize the possibilities of using Aerial Data Collection Device described in agriculture academic studies, to understand how these devices are being used in research carried out by Brazilian universities. The research is limited to the results of thesis and dissertations between the years 2015 and 2017, considering the graduate programs of the USP, UNICAMP, and UNESP. Five categories were defined regarding the propensity for the use of Aerial Data Collection Devices: Soil Diagnosis, Plant Diagnosis, Management of Grazing Areas, Crop Management, and Hydrographic Monitoring. It was identified that more research is needed to reflect on how science can help its application in this strategic productive sector.

Keywords: Research data · Data collection · Aerial data collection device · Drone agricultural research

1 Introduction

Access to information as a key success factor in all areas of human activity gains prominence with the intensive adoption of Information and Communication Technologies (ICTs). One of many characteristics identified in the economically developed countries in the 21st century is the intensive use of technologies addressed to the digital informational environment, specifically computers and mobile devices connected to the internet, which caused an effect of incorporation of several digital services in professional and entertainment activities [35]. This fact implies in a scenario characterized by the increase

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in the volume of information generated and shared, the speed of dissemination of that content, and the variety of informational objects present in the accessible data flows in the digital environment [28].

The education, research, and outreach projects activities are also impregnated by this effect: technological development has allowed academics to carry out new practices, considering the possibilities of collecting, processing, and recovering large amounts of research data. The science area has provided these new options by increasing the number of data generated and collected from technological devices such as microscopes, telescopes, satellites, among others [36]. Those new options currently transform the phenomena of nature into electrical signals, standardized and machine-understandable, with little or no human intervention.

Although science increasingly relies on actions of data collection and processing, it should be noted that part of the technological body was not designed to deal with characteristics such as scalability and heterogeneity of data, which ends lacking the quality of the information that will support the scientific research process. This problem is associated with the requirement to consolidate e-science, which is strongly dependent on the fall of barriers to open access to research data, and grounded on an infrastructure based on the internet and digital devices [19].

One of the most relevant research domains in Brazil is the agricultural area, that places the country as the most productive in Latin America, and fifth in the world ranking [40]. Agriculture includes a set of activities associated with nourishment, environmental management, and human culture, and may be diversified concerning the techniques used and in terms of production systems and social organization [33]. Activities such as the management of soil fertility and plant varieties, the adaptation of animals to the characteristics of the local environment, and the management of environmental resources are inserted in the practices carried out by farmers [42].

Agricultural practices passed by transformations during the 19th and 20th centuries, influenced by the development of technologies during and after the Second World War which resulted in the mechanization of activities performed by farmers and the development of new chemical and biological products [33, 42, 47].

The agricultural modernization process in Brazil was influenced by the international model and the local incentive for scientific and technological production research. This incentive was supported by the public sector since the beginning through the establishment of departments, centers, institutes, and public companies, especially through the research performance performed by the Brazilian Agricultural Research Company [17, 21].

Article 12 of law No. 8.171/1991 [8], which provides the Brazilian Agricultural Policy, establish that agricultural research is the practice of research generated or adapted from the biological knowledge of the integration of the various ecosystems to increase productivity and generating technologies focused on animal and plant health, as well as the preservation of health and the environment.

The research of development technologies and innovation for agriculture collects and generates a variety of data, ranging from results of practical experiments in greenhouses and laboratories to data generated from the use of electronic remote sensors [23], in which the data is regularly generated in diverse data types, with a high expense, and through experiments that sometimes consume a lot of time, implying an urge for optimization, from data integration and reuse processes [15].

With the occurrence of different techniques for data collection in agricultural research, this investigation is constructed in the context of the aerial survey - a set of operations to obtain land, air, and sea data from embedded technologies for data collection and transmission using the technological resources from aerial platform and control station [1].

This research addresses the Unmanned Aerial Vehicles (UAVs) used like an instrument applied in aerial data collection activities within studies in the agricultural area. It starts with the following questions: I) What is the propensity to use Aerial Data Collection Device (ADCD) in agricultural area research as a resource for data collection? ii) What results may be generated with the use of this type of resource? Considering those questions, the objective of the research is to categorize the possibilities of using ADCD for data collection in agricultural research, paying attention to how this device is being used in research performed by higher education institutions.

The Information Science comprises the area of knowledge that is interested in research related to studies on research data, addressing subjects such as i) digital repositories and curation of research data [39]; ii) use and reuse of research data [16], and; iii) research data management [18]. Thus, it is considered that the Information Science perception may (and it should) also be applied in the context of agricultural research data, focusing on the use of technological devices in data collection and processing activities.

Based on the Information Science perspective, the research scope is oriented towards the information flows and the phases of the data life cycle, with special attention to the data collection phase [37], in a sense that the technical resource involved becomes only the instrument through which the data collection is carried out.

2 Theorical Framework

The use of UAVs may replace the use of manned aircraft, bringing as main benefits i) the reduction of operational cost (cost of an hour of flight, maintenance, among others); ii) greater application flexibility in obtaining data; iii) dispatch of transport and storage due to its small size; iv) convenience in takeoff and landing operations, and; v) technical capacity for shooting and collecting photographic records with a resolution similar to manned aircraft. In addition, the UAV foregrounds other aerial data collection platforms for having the ability to perform low-altitude flights and, consequently, suffer fewer impacts from climatic factors [34, 49].

In 2010, the Brazilian Department of Air Space Control defined UAV as an air vehicle designed to operate without a pilot on board, with a payload onboard and not used for recreational purposes. This definition includes all three-axis controllable airplanes, helicopters, and airships, therefore excluding traditional balloons and model airplanes [11].

For DECEA, a department of the Brazilian Ministry of Defense, the term UAV is considered obsolete by the international aeronautical community because the main aviation organizations no longer use the term "vehicle" and due to the requirement for an existing system to carry out the flights [9]. In this sense, the Brazilian Ministry of

Defense replaced the acronym UAV with RPA, referring to the term Remotely Piloted Aircraft in the English language [9]. In this sense, an RPA is an unmanned aircraft piloted from a remote pilot station [9].

Another term that refers to this aerial platform is DRONE, a term from the English language meaning a low continuous humming sound, observed in scientific publications and commercial communications. The term DRONE is associated with a more generic and informal concept has no technical protection or legal definition in Brazil, and it can be used to describe any unmanned flying object, even for recreational use [10].

Considering the presence of more than one designation for these instruments (UAV, RPA, and even DRONE) emerges the requirement to use in this study the definition of Aerial Data Collection Device (ADCD) to refer to the set determined by the aerial platform and the control platform, through embedded technologies, has the ability to carry out aerial data collection.

Operations with ADCD are restricted to airspace, involving autonomous, semi-autonomous, or remotely operated aircraft, authorized and coordinated by the ANAC through Brazilian Special Civil Aviation Regulation No. 94/2017. This regulation is an instrument complementary to the standards to operate this type of device, established by DECEA and by the Brazilian National Telecommunications Agency (ANATEL) [2].

Initially, the ADCDs were designed for military purposes in the 1950s and 1960s. These devices were developed to facilitate the gathering of information on signs of hostilities, obtaining enemy reconnaissance photographs [6].

Over time the use of ADCDs changed to a more flexible application to other scenarios, such as surveillance actions; cartographic and oceanographic studies; search and rescue missions in difficult areas; road traffic control; foreign borders control; monitoring of polluting gas emissions, and; wildfire monitoring [41].

It was possible to follow that the ADCD for data collection in agricultural scientific research is an ongoing discussion. Besides, there is an open debate about the recognition of the importance of regulation about the use of this kind of technological resource in agricultural research by the Commission of Constitution, Justice, and Citizenship (CCJC) from the Brazilian Federal Senate of Brazil: Bill - PLS No. 698/2015. The bill seeks to update Law No. 8,171/1991 and includes, among the purposes, the prioritization of the use of this type of technological tool [8, 30].

A Brazilian pioneering initiative to use an ADCD in agriculture was made by the Radio Assisted and Autonomous Reconnaissance Aircraft Project (ARARA) developed in association with the Institute of Mathematical and Computing Sciences (USP), EMBRAPA, and AGX Technology. The ARARA project had the goal to replace the use of conventional aircraft to gather data and images for monitoring areas subjected to environmental issues [22].

According to [41], since the use of ADCD in agricultural scientific research is a recent phenomenon, some Brazilian universities use it as a resource to expand the amount of data available in the development of scientific studies, in addition to being a key element in the capture of resources before development agencies.

3 Methodological Procedures

This research starts from a systematic collection of research in the agricultural area in which the ADCD are used or referenced in data collection. The research universe is the results of studies in thesis or dissertations formats, with a sample restricted to publications of the Postgraduate Programs (PGP) of the University of São Paulo (USP), State University of Campinas (UNICAMP), and São Paulo State University (UNESP), published in the years between 2015 and 2017, available in the respective institutional online repositories.

The selection criteria were defined on the concept that these documents (thesis and dissertations) need to correspond to the results of research that are in experimental status with a single and defined topic, developed in the scope of a PGP. Thus, it is possible to observe the characteristics of the use of these devices in each educational institution, as well as the thematic areas that each PGP research is investigating. It was considered to establish the sample on those three state universities of São Paulo by the excellent performance that they present in the scientific environment such as the Web of Science [13], and because the state of São Paulo has the highest number of ADCD records enabled for operation, representing 35.20% of the total records of this type of aircraft in Brazil [3].

The repositories of Theses and Dissertations of the three educational institutions were used as a source for obtaining the studies to be analyzed. The procedure employed was to access documents through the advanced search interfaces available to retrieve the document set. The search filters were configured to retrieved only documents published between 2015 and 2017, and types of documents retrieved only composed on thesis or dissertations forms. The search expressions were used were: “Non-Manned Air Vehicle”, “Drone”, and “Remotely Piloted Aircraft”, concatenated with the terms “Agriculture”, “Agricultural”, “Livestock” and “Environmental”. All those expressions were written in Portuguese, respectively: “Veículo Aéreo Não Tripulado”, “Drone” and “Aeronave Remotamente Pilotada”, concatenated with the terms “Agricultura”, “Agrícola”, “Pecuária” and “Ambiental”.

After recovering the scientific production in those repositories, it was made a classification of the results from the analysis of fragments of the texts that cited at least one of the terms: “UAV”, “RPA” or “DRONE”. This procedure sought to filter, by reading the title and the abstract, the existence of adherence to the subject analyzed.

The Content Analysis [5] was applied for the treatment of the corpus, which consists of a set of communication analysis techniques intended to obtain indicators (quantitative or not) by systematic procedures and objectives of content description in the messages, that allow the inference of knowledge related to the conditions of production and reception (inferred variables) of these messages.

It was chosen the technique of category analysis, which implies the selection of qualitative criteria of choice and categories for the association of the content present in the analyzed messages; in this case, textual domain messages [5]. The definition of the categories was performed after the analysis of the corpus and was based on principles of homogeneity and mutual exclusion, conceptually based on the possibilities of data collection with ADCD in agricultural research.

4 Results and Discussion

The results obtained from the sample analysis allow observing a partial view of how Brazilian higher educational institutions use ADCD in agricultural research. After applying the methodological strategy, it retrieved 460 thesis and dissertations from the institutional repositories: 11 from USP, 6 from UNICAMP, and 443 from UNESP. A total of 442 thesis and dissertations were discarded during the classification of results because it was verified that has no thematic adherence to ADCD use to collect data in agricultural research. In other words, they did not contemplate topics related to Agriculture. The discard pile was formed by 8 documents from USP, 3 documents from UNICAMP, and 431 documents from UNESP. After discarding, the analyzed corpus was formed by 18 documents, which are synthesized in Appendix A. The corpus consists of 12 documents from UNESP, 3 documents from USP, and 3 documents from UNICAMP (Appendix A).

From the content analyzed were defined five categories to represent the types of use provided by the ADCDs in data collection within agricultural research. The Table 1 presents the five defined categories: Soil Diagnosis (SD), Plant Diagnosis (PD), Management of Grazing Areas (MGA), Crop Management (CM), and Hydrographic Monitoring (HM). It can be observed the definitions established for each class; the consulted works that are associated with each one; as well as the attributes of the data collected in each investigation.

Table 1. Categorization of ADCD use in agricultural research.

Category	Category description	Analyzed document	ADCD data collected during the research
Soil Diagnosis (SD)	The analytical process to qualify the soil based on characteristics such as fertility, typology, and structure.	Ávila [4]	Soil type mapping.
		Tagliarini [44]	Estimation of soil losses by erosion.
Plant Diagnosis (PD)	The analytical process to determine crop Phyto-physiognomy and identify the presence of pests and threats.	Moriya [31]	Spectral characterization of healthy and diseased sugarcane, to identify the most suitable wavelengths for detecting diseases.
		Martins [26]	Coffee mapping: healthy, the initial state of infection or severely infected.
		Borges [7]	Plant ecophysiological information.
		Vasconcelos [48]	On the effects of applying doses of phosphorus and potassium on growth in *Khaya Senegalensis* plants in the implantation phase.
Management of Grazing Areas (MGA)	The systematic practice of planning, strategies, and control of factors related to organization and the welfare of livestock in grazing space.	Teixeira [45]	Management and rotation of animals in grazing areas.

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Table 1. (*continued*)

Category	Category description	Analyzed document	ADCD data collected during the research
Crop Management (CM)	Activities of planning, strategies, and control of factors related to the development of the crop, such as quality of the vegetation cover, the arrangement of plants in the area, and the application of techniques to improve productivity.	Maldonado Júnior 24]	Counting of fruits of green oranges to estimate quantities of fruits present in the fruit trees.
		Miyoshi [29]	Spectral characterization of vegetation species at the foliar and crown level to contribute with information that can be used for forest monitoring.
		Souza [43]	Fault mapping in sugarcane planting lines; Represent variability of the productivity field.
		Criado [14]	Monitoring the recomposition of reforested areas.
		Torres [46]	Monitoring of forestry activities, estimation of forest volume and biomass, and biodiversity mapping.
		Santos [38]	Mapping of sugarcane areas.
		Martello [25]	Height and productivity estimation; evaluation of sugarcane fields.
		Niemann [32]	Information related to the surface as plant canopies.
		Chiacchio [12]	Mapping of rural cultures and properties.
Hydrographic Monitoring (HM)	The state of surveillance of availability of water resources and the control of irrigation systems.	Marton [27]	Environmental monitoring; Water frames.
		Garcia [20]	Environmental diagnosis of the physical environment of the hydrographic basin.

The stacked bar graphic element of Fig. 1 summarizes the incidence of studies for each category differentiated by the institution where the research was carried out.

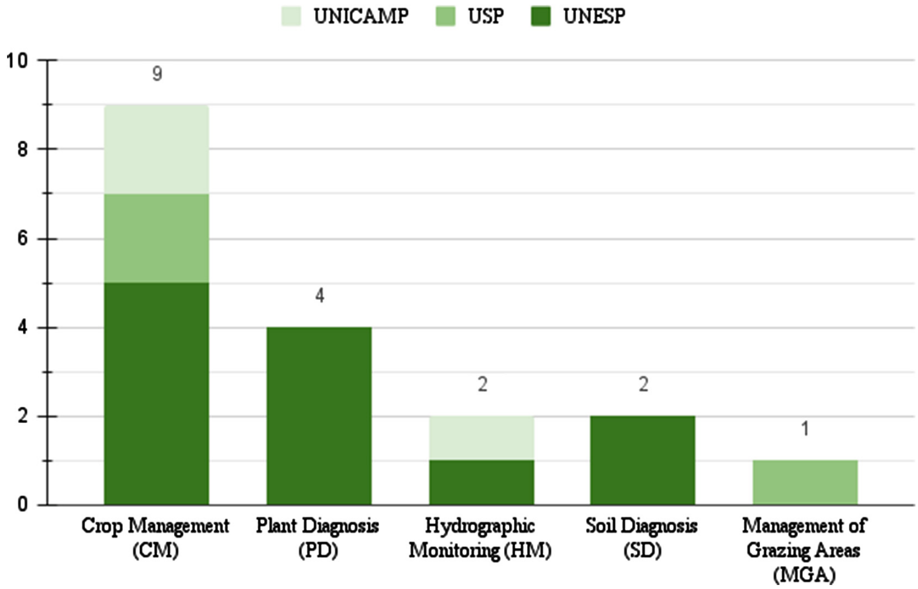

Fig. 1. Incidence of research by category and by institutions.

The category in which most of the documents were associated was Crop Management, which includes the types of use of ADCD related to obtaining information on productivity in the harvest, monitoring of environmental and productive areas, and monitoring of forests and planting failures. A total of 9 documents were associated with this category, 5 related to UNESP, carried out in the Cartographic Sciences and Geography PGP (2 research each), and Agronomy. The 2 investigations carried out at USP correspond to one in the area of Sciences and the other in the area of Agricultural Systems Engineering, and 2 studies were developed at UNICAMP, one in the area of Agricultural Engineering and the other in the area of Geography.

The category Plant Diagnosis includes plant diagnostic studies at a micro level, related to the chemical and biological properties of each plant that make up the tillage, such as measurement of macronutrients, abiotic changes, control of fruit ripening, and detection of hydric and or nutritional stress. A total of 4 documents of the corpus were associated with this category, being the second most representative category in the analyzed context. All the studies associated with this category were carried out at UNESP, two of them in the area of Cartographic Sciences, one in Agronomy and the other in Ecology.

The category defined as Hydrographic Monitoring comprises ADCDs to support strategies for the use of water resources, mapping and geo-referencing of hydrographic basins, and monitoring of the degradation of water areas. Two documents of the corpus were associated with this category, one being developed in the Mechanical Engineering PGP of UNICAMP, and another in the UNESP at the Agronomy PGP.

The category Soil Diagnosis presents ADCD applications for data collection that assist the analysis of soil moisture and temperature, monitoring of erosive processes, and measurement of hydric and nutritional deficiencies in plantations. Two documents were associated with this category, both carried out in UNESP, one in the area of Agronomy and the other in Geography.

Studies related to the observation of the movement of cattle in grazing areas and the elaboration of rotation strategies were classified in the category Management of Grazing Areas, in which only 1 research was associated with this category carried out in the PGP of Sciences at USP.

Regarding the representativeness of the categories concerning the sample of documents analyzed, research related to the use of ADCD for Crop Management (50%) predominated, followed by the use of ADCD in Plant Diagnostics (22%). The categories Soil Diagnosis and Hydrographic Monitoring obtained the same percentage of representativeness (11% each) and as a less representative category the use of the device for Management of Grazing Areas (6%).

Besides, it was possible to establish a perception of the use of ADCD by higher educational institutions and by areas of knowledge that work with agricultural research. In general, there was a predominance of the use of ADCD in the areas of Agronomy, Geography, Cartographic Sciences, Engineering (Agricultural, Agricultural Systems or Mechanics), and Sciences.

In summary, the ADCD use applied to Soil Diagnosis is more representative in the areas of Agronomy and Geography; while for Plant Diagnosis, the use of this type of device predominates in areas such as Cartographic Science, Agronomy, and Ecology.

Regarding the Management of Grazing Areas category, the only associated document was the result of an investigation carried out in the area of general science. The investigations that used ADCD to obtain data were predominant in the areas of Geography, Cartographic Sciences, and Engineering (Agricultural or Agricultural Systems), followed by Agronomy and Sciences. The Hydrographic Monitoring included the use of this type of device in research carried out in programs in the areas of Agronomy and Mechanical Engineering.

An outstanding fact is that there is a higher frequency of use of ADCD at UNESP by researchers from the campus of the Faculty of Sciences and Technologies, located in the municipality of Presidente Prudente. The existence of an agreement between this campus and the Finnish Geodesy Institute (FGI), called Unmanned Airborne Vehicle-Based 4D Remote Sensing for Mapping Rain Forest Biodiversity and its Change in Brazil (UAV_4D_BIO), which involves mapping and monitoring of the biodiversity and the use of ADCD for obtaining images and geospatial data in forest mapping.

Regarding how each investigation used or mentioned the use of ADCD, it was observed that 50% of the research used ADCD to obtain their data, including the description of the elements involved in the procedure for using the device. A total of 11% of the research also used the resource for data collection but did not describe its mode of use, only presenting the data gathered. A part corresponding to 39% of the total of analyzed research did not use ADCD for data collection. However, they referred to its use as a possibility of improvement in the data collection carried out, or as an example to replace the method applied in their studies.

5 Conclusions

Through the analysis of thesis and dissertations that used or mentioned the use of ADCD as a data collection device, it was possible to establish categories that could facilitate the understanding of the possibilities and implications of the use of this type of device in agricultural research. These results may contribute to researchers who present the need to collect data and could project trends of applying ADCD to obtain data with a higher level of quality and economic benefit compared to other existing resources.

Information Science area contributed to this research because it allowed us to glimpse the information flows related to the use of ADCD in the collection and processing of data in agricultural research since it was necessary to understand the main attributes of the data treated in each document analyzed to establish the definition of the categories. In addition, the area contributed with its interdisciplinary vision, allowing to discussion data collection activities from a modern and innovative device, but with a perspective directed to the content that is generated, and not to the technical aspects of the machine.

The results obtained determined that the use of ADCD for data collection in agricultural research is already a reality and that it can be applied both in Nature Sciences (e.g. Agronomy and Biology) and Math-Sciences (e.g. Engineering and Cartography) and Humanity Sciences (e.g. Geography) or any specialization that address research within the agricultural context.

In the analyzed sample, it was verified that the propensity is towards studies that focus on improvements in Crop Management, although considering the geographical location and the predominance of the agricultural sector, it is possible to extrapolate to other regions that are eager for developments technologies that optimize processes paramount to them.

It should be noted that because it is an instrument that recently became part of research data collection procedures, it is necessary to warn about aspects involved in its application in the scientific area, mainly in the description of its use procedure when publishing the studies. In this sense, other developments are glimpsed that can also be covered by Information Science, such as the singularity related to curating the data obtained through ADCD, and what are the essential requirements for a repository to support the availability of the data collected with this type of device.

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Appendix A. Synthesis of the Analyzed Corpus

Year	Advisor	Author	Title	University	PGP	Location (Municipality)
2015	IMAI, N. N.	MORIYA, E. A. S.	Identification of spectral bands for the detection of healthy and sick sugarcane cultures using a hyperspectral camera embedded in UAV	UNESP	Cartographic Sciences	Presidente Prudente
2015	PANCHER, A. A.	ÁVILA, M. R.	Scenarios of urban expansion and legislation and reflections on tree and shrub cover in the city of Americana-SP	UNESP	Geography	Rio Claro
2016	BARBOSA, J. C.	MALDONADO JUNIOR, W.	Estimation of the number of green fruits in orange trees using digital images	UNESP	Agronomy	Jaboticabal
2016	FIORAVANTI A. R.	MARTON, A. S.	Linear control of the trajectory of the robotic airship with quadruple propulsion	UNICAMP	Mechanical Engineering	Campinas
2016	GALO, M. de L. B. T.	MARTINS, G. D.	Inference of nematode infection levels in coffee culture from remote sensing data acquired in multi-scale	UNESP	Cartographic Sciences	Presidente Prudente
2016	IMAI, N. N.	MIYOSHI, G. T.	Spectral characterization of inland Atlantic Forest species at leaf and crown level	UNESP	Cartographic Sciences	Presidente Prudente
2016	LAMPARELLI, R. A. C.	SOUZA, C. H. W.	Acquisition of information at sugarcane field level using data from an Unmanned Aerial Vehicle (UAV) under different methodologies	UNICAMP	Agricultural Engineering	Campinas

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Year	Advisor	Author	Title	University	PGP	Location (Municipality)
2016	MORELLATO, L. P. C.	BORGES, B. D.	A new perspective to understand functional connectivity by integrating landscape and Phenology	UNESP	Ecology	Rio Claro
2016	PIROLI, E. L.	CRIADO, R. C.	Change in land use and land cover in municipalities in Paranapanema from 1984 to 2014	UNESP	Geography	Presidente Prudente
2016	TECH, A. R. B.	TEIXEIRA, B. E.	Use of unmanned aerial vehicle with fixed-wing to monitor and collect images of animals and environments in rural properties	USP	Sciences	Pirassununga
2016	TOMMASELLI, A. M. G.	TORRES, F. M.	Assembly and Evaluation of a Laser Scanning System embedded in UAV	UNESP	Sciences	Presidente Prudente
2016	VASCONCELOS, S. T.	VASCONCELOS, R. T.	Phosphate and potassium fertilization in the implantation of *Khaya senegalensis A.Juss*	UNESP	Agronomy	Jaboticabal
2017	CAMPOS, S.	TAGLIARINI, F. S. N.	Geoprocessing techniques applied to quantify soil losses in a hydrographic basin	UNESP	Agronomy	Botucatu
2017	CAMPOS, S.	GARCIA, Y. M.	Environmental diagnosis of the Ribeirão Pederneiras River Basin - Pederneiras / SP	UNESP	Agronomy	Botucatu

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Year	Advisor	Author	Title	University	PGP	Location (Municipality)
2017	CASTILLO, R. A.	SANTOS, H. F.	Regional competitiveness of the sugar-energy sector in the mesoregion of Minas Gerais / Alto Paranaíba: Globalized scientific agriculture and socio-environmental implications in the city of Uberaba / MG	UNICAMP	Geography	Campinas
2017	FIORIO, P. R.	MARTELLO, M.	Estimation of height and productivity of sugarcane using images obtained by remotely piloted aircraft	USP	Agricultural Systems Engineering	Piracicaba
2017	SILVA, T. S. F.	NIEMANN, R. S.	Comparison of filtering methods and generation of digital terrain models from images obtained by an unmanned aerial vehicle	UNESP	Geography	Rio Claro
2017	TECH, A. R. B.	CHIACCHIO, S. S. R.	An unmanned aerial vehicle with rotary-wing in the activity of mapping and image collection in precision agriculture and animal monitoring	USP	Sciences	Pirassununga

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