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Overcoming educational barriers for precision agriculture adoption: A University Diploma in Precision Agriculture in Argentina

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Abstract.

The lack of educational programs in Precision Agriculture (PA) has been reported as one of the barriers to adoption. Our goal was to improve professional competence in PA through education in crop variability, management, and effective practices of PA in real cases. In the last 20 years, different efforts have been made in Argentina to increase the adoption of PA. The Universidad Nacional de Río Cuarto (UNRC) launched in 2021 the first University Diploma in PA, a 9-month program to train agronomists in Argentina. The training program was organized in four modules with a total of 230 hours. The objective of the program was to develop skills in precision agriculture and data analysis tool to implement site-specific management. Module I served as an introduction to PA, Module II included precision agriculture equipment and a seminar with agronomists providing PA services. Module III focused on practical geo-statistics, analysis of variable rate research trials, and econometrics for PA. The program concluded with an integrated project,

where students presented a case study with defined farmer's management goals and needs. In this project, students developed a pipeline of work using PA tools to address farmer's goals and they quantified the value of applying PA techniques. Students presented their case study with live broadcasting to the public. A UNRC proprietary digital learning platform was implemented to coordinate the whole program. This was the first Diploma in PA organized and taught by a National University in Argentina. Professors belonged to UNRC, Instituto Nacional de Tecnología Agropecuaria (INTA), Universidad Católica de Córdoba, Universidad Nacional de Córdoba and Consejo Nacional de Ciencia y Tecnología (CONICET). A total of 32 agronomists graduated in December 2021. A survey conducted at the end of the program showed that resources for statistics education and site-specific crop management at a graduate level are not limiting right now, since precision technology is continually improving and becoming more accessible. Teaching PA will be further supported by the data and digital age. There is a need to develop more integrated training programs such as the one presented here, with a holistic view of PA on how it can be applied to increase the sustainability and productivity of current and future food production systems.

Keywords.
GIS, remote-sensing, teaching, site-specific management

Introduction

The lack of educational opportunities was reported as one of the barriers to adoption of PA (Lowenberg-DeBoer and Erickson 2019, Melchiori et al. 2018). In Argentina there are some initiatives to promote PA, such as the Argentina Innovation Plan 2020, a federal government initiative to promote the development of agriculture, which recognized precision agriculture as one of the strategic areas. Similarly, at the state level, the province of Córdoba passed the state law 28.990 of Good Agricultural Practices, which includes PA as a good practice. Furthermore, in the Strategic Plan 2017-2023, the National University of Río Cuarto, (UNRC 2017) foresees the creation of new academic programs to meet the demand from agronomists. Therefore, this need was met by this University Diploma in Precision Agriculture (DISAP) at the School of Agronomy and Veterinary of UNRC (UNRC, 2017)(Melchiori et al. 2018).

The National University of Río Cuarto was a pioneer in Argentina, offering an undergraduate course in Precision Agriculture as part of the bachelor's in Agronomy (11 semesters) starting in early 2000. Likewise, the Instituto Nacional de Tecnología Agropecuaria (INTA) has a long trajectory of research and extension on PA in Argentina (Bragachini and Mendez 2005; Melchiori et al. 2013; Melchiori et al. 2018) (Bongiovanni and Lowenberg-DeBoer, 2019) (Bongiovanni, Mantovani, Best, & Roel, 2006). The UNRC, INTA, and other institutions used to organize short training for agronomists in Argentina about different topics in PA. In those training events, it was identified the need of generating a new integrated program on PA for agronomists to acquire both the theory and the practical knowledge. A graduate course in Site-Specific Management is offered at UNRC. In March 2021 the UNRC launched the first University Diploma in Precision Agriculture in Córdoba Argentina. The program was dedicated to agronomists that graduated with a bachelor's in agronomy from a program of a minimum of 4 years. The goal is to train agronomists to develop their skips ins PA to apply in their daily activities. A total of 12 professors participates in the courses/seminars (50% with Ph.D.- 50% with MSc degree) from UNRC, INTA, Universidad Nacional de Córdoba (UNC), and Universidad Católica de Córdoba (UCC).The National University of Rio Cuarto was a pioneer in Argentina offering an undergraduate course in Precision Agriculture as part of the bachelor's in Agronomy (11 semesters) starting in early 2000. Research projects on nitrogen management in corn were conducted showing the impact of PA to increase profits and nitrogen use efficiency (Balboa 2014; Esposito 2013) as well as other inputs management (Cerliani 2019). The Instituto Nacional de Tecnología Agropecuaria (INTA) has a long trajectory of research and extension on PA in Argentina (Bragachini and Mendez 2005; Melchiori et al. 2013; Melchiori et al. 2018). Until 2020, the INTA developed 18 National Workshops in PA reaching thousands of farmers and agronomists from all over Argentina. The UNRC, INTA, and other institutions used to organize short training for agronomists in Argentina about different topics in PA. In those training events, it was identified the need of generating a new integrated program on PA for agronomist to acquire both the theory and the practical knowledge. A graduate course in Site-Specific Management is offered at UNRC. In March 2021 the UNRC launched the first University Diploma in Precision Agriculture in Cordoba Argentina organized by a National University. One year before, the Universidad Catolica de Cordoba launched a Diploma in PA with a program length of 104 hours. The UNRC University Diploma in PA is dedicated to agronomists that graduated with a bachelors in agronomy from a program of a minimum of 4 years. The goal is to train agronomists to develop their skips ins PA to apply in their daily activities. A total of 12 professors participates in the courses/seminars (50% with Ph.D.- 50% with MSc degree) from UNRC, INTA, Universidad Nacional de Cordoba (UNC), and Universidad Católica de Cordoba (UCC).

The objective of this paper is to review and quantify the impact on the professional development of students of the University Diploma in Precision Agriculture. The program is offered by the Universidad Nacional de Río Cuarto (Argentina) as a contribution to promoting the adoption of PA technologies by addressing educational barriers.

Program structure

The program at the University Diploma in Precision Agriculture (DISAP) includes courses and seminars organized into four modules **(Table 1)**. The program includes a total of 11.5 credits (230 hours). The first module involves an introduction to PA by a special guest, and two courses: one on GIS and the second on site-specific soil characterization. This module was intended to refresh on basic topics related to PA. The second module has a specific course on Precision Agriculture equipment that is intended to look at the state of the art in machinery and tools applied to PA. The seminar in module II has the goal of presenting a different case study and professional experience from agronomists in Argentina. Recognized specialists in the private sector are invited to share their experiences with the students. The third module of the program has two courses, one in spatial econometry and geo statistics and another in site-specific crop management. This last course intends to integrate many of the concepts, techniques and tools learned previously in the program.

The final module (IV) has the objective of developing a case study by the students. The first seminar presents different tools and strategies to develop their projects. Students start the seminar by defining the problem under study and how they are planning to address it presenting a value purpose. Students have a month to collect the data and pursue different analyses to answer their questions and show the value of PA as a tool in production systems. The last seminar is open to the public and is a live broadcast, where students present their case studies along with a full report of their results. The goal is to tackle a real situation like the ones that they will need to solve with farmers. Requirements to pass each course and seminar are to approve all activities proposed and to meet the 80% of attendance. The final seminar presentation and report are graded.

Table 1. Program structure.

Module	*Seminar/Course title*	*Credits*
I	1. Seminar: Introduction to Precision Agriculture.	0.5
	2. Course: Geographical Information Systems and tool to identify spatial variability.	2
	3. Course: Site specific soil characterization	1
II	1. Course: Precision Agriculture Equipment and tools	1
	2. Seminar: Study cases on Precision Agriculture in Argentina	0.5
III	1. Course: Spatial econometry and geo-statistics	2
	2. Course: Site Specific Crop Management	2
IV	1. Seminar: Case study development	2
	2. Seminar: Case study presentation	0.5

Class of 2021: first cohort

The first cohort of students in this program started on March 2021 and finished in December 2021. The original program structure was intended to include 30% of the credits to be taken virtually and 70% in person at UNRC Campus (Río Cuarto, Córdoba, Argentina). Because of the Covid19 pandemic, the Academic Committeeacademic committee adapted the Program to be taught fully virtual. A UNRC proprietary Virtual Teaching Platform (**Fig. 1.a**) was set up as the main structure to organize and develop the Program. This platform has different tools: news, activities, materials, contact information, forum discussion, quizzes, and videoconference capabilities. All the classes were recorded. The Zoom videoconference software (**Fig. 1.b**) was implemented to live-stream classes or to record tutorials. All videos were organized in a special private YouTube Chanel to be available 24-hour for all the students (**Fig. 1.c**). Each professor established group or individual virtual office hours. The final seminar was set as an in-person event at UNRC Campus and broadcasted live in YouTube (**Fig. 1d-f**). Feedback recovered from surveys at the end of each course and seminar mentioned that the virtual learning allowed the students to follow the Program while continuing with their normal professional activities. This was analyzed by the academic

committee, and it was decided that the 2022 cohort will be a mix virtual and in-person program.

AllA total of 32 students finalized the 2021 cohort. Overall students were able to solve the different activities proposed by the professors. At the beginning of the program, efforts were focused on training students with GIS skills. Courses were graded with a scale from 1 to 10, the minimum grade to pass the course is 6. There was a positive trend in students' grades towards the end of the program and the mean grade for the final case study was 9.1 (**Fig. 2**).

Figure 1. UNRC Virtual teaching Platform (a), virtual zoom discussion with students (b), YouTube Video Channel (c), Case study presentation broadcasting (d), PA pipeline for case study development (e), and picture of the first cohort of students after presenting their case study in person at UNRC Campus.

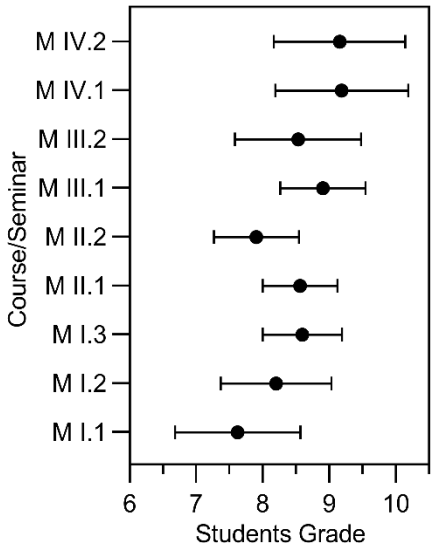

Figure 2. Students grade by course or seminar. Black dot indicates the student grade mean, and whiskers indicates the standard deviation. M: module

Case studies summary

Students worked in groups to elaborate their final case study project. A list of project titles, data layers implemented, and authors is presented in **Table 2**. After finishing the program seven groups (2 orals and 5 posters) presented their case study at the Second Latin American Congress of Precision Agriculture in March 2022 **(Table 2)**. In their projects, students described the problem and generated/processed different data layers to perform an analysis and address their research question. This allowed to show the value of PA techniques to account for resource variability to implement site-specific management.

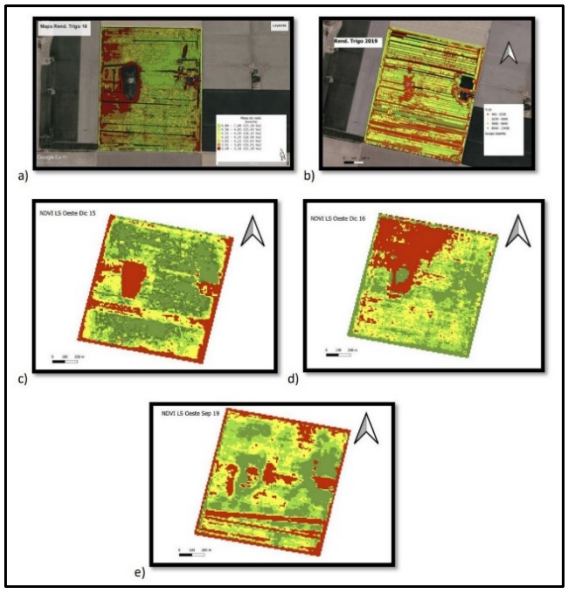

Figure 3. Different data layers wheat yield 2016 (a), 2019 (b), NDVI dec 15 (c), dec. 16 (d) and sep 2019 (e); to characterize one field to delineate management zones in the study case "Experiences in precision agriculture variable-rate inputs in high yielding corn in Southeast of Córdoba" by Lucero M. and Naville R.

Table 2. Study case title, data layers involved, and authors in Module IV

id	Study case title	Data layers implemented	Authors
1	Mechanical resistance maps: Impact of the use of digital tools for the interpretation of the development of experimental maize materials in a Typical Hapludol of the east of Río Cuarto	Satellite (Google Earth), RGB Drone, mechanical resistance, soil moisture, experiment layout.	Albornoz, M; Bonifacino A; Cardetti, C
2	Nitrogen and seeding rate economic optimization by environment according to planting date and previous crop	Yield map, RGB drone, management zones, NDVI from satellite, soil types, experiment layout.	Azcurra Moriena, M; Gatica, PJ
3	Management zones delineation to determine the convenience of implementing variable seeding rate in field managed without Precision Agriculture	Yield map, soil sampling gride, elevation map (RTK), NDVI (Satellite), topographic compound index (CTI), management zones, P and OM	Bernardini, J I
4	Precision agriculture: management of variable rate phosphorus in the South of Córdoba	Elevation, yield map, NDVI (satellite), management zones, P, OM, pH.	Bovetti, G; Morales, M
5	Nitrogen by seeding rate interaction model to implement variable rate inputs in farmers' fields.	Satellite (Google Earth), experiment layout, yield map, elevation, electrical conductivity (30-90cm), management zones	Catani, M; Diaz, SE
6**	"Precision nutrient mining": convenience of using management zones according to a simplified nitrogen balance and corn nutrient extraction	Yield map, N extraction, management zones.	Corigliano, JA
7*	Evaluation of altimetry maps generated by different agricultural machinery as a data layer for fertilizer prescription	Satellite (Google Earth), elevation from yield maps, spraying map, seeding operation, tillage operation, electroconductivity map, topographic compound index.	Di Menza, S; Stefani, EJ
8*	Carbon footprint: impact of corn production in southeast Buenos Aires	Experiment layout, N and seeding rate prescription maps, yield maps, management zones, vegetation indices (satellite).	Etcheto, A
9*	Corn production based on an optimal seeding rate	Satellite (Google Earth), yield maps, seeding	Flores, L; Maricioni,

	and nutritional combination in Las Lajitas (Salta)	rate prescription map, fertilizer prescription, NDVI (satellite).	G; Picco, N
10	Selection of data layers to determine management zones in the South of Córdoba	Elevation, yield map, NDVI (satellite), management zones, P, OM, pH.	Grancara, GA; Grosso, M
11*	Field weed survey by automatic detection technique	Aerial imagery (drone), herbicide prescription, weeds map.	Barrionuevo, N; Guaita, N
12	Vegetation indices evaluation at different corn growth stages	Satellite (google earth), NDVI, GNDVI, NDRE (satellite), yield maps.	Lopez, MJ; Vitelli, N
13**	Experiences in precision agriculture variable rate inputs in high yielding corn in Southeast of Córdoba	Satellite (Google earth), experiment layout, yield map, NDVI (satellite), management zones, electroconductivity, seeding rate prescription map.	Lucero, M; Naville, R
14**	Correlation between within field corn production variability and vegetation indices: NDVI, EVI and SAVI, in South of Córdoba	Satellite (Google Earth), yield maps, NDVI, EVI, SAVI (satellite).	Nieto, A; Ohanian, I; Saleme, K
15	Evaluation of variable rate input management in Central north Córdoba	Soil maps, electroconductivity (30-90cm), elevation, soil sampling, management zones, fertilizer and seeding rate prescription map, yield maps.	Ramello, IS; Tochetto, F
16	Zoning method for environment evaluation to determine land value based on potential productivity	Satellite (Google Earth), soil maps, soil test sampling points, land value, NDVI (satellite), electroconductivity	Scavuzzo, S; Tomasini, SL

*Seven of this case studies were presented (*poster, **oral) by the authors in the Second Latin American Precision Agriculture Congress, Córdoba, March 2022. This event was organized by the Latin American Society of Precision Agriculture, the Universidad Nacional de Río Cuarto, the Instituto Nacional de Tecnología Agropecuaria, the Universidad Nacional de Córdoba, and the Universidad de La Pampa.*

As it can be observed in Table 2, all the topics covered in the final seminar respond to key questions that farmers currently have.

A revision of the 16-case study indicated that 16 different types of data layers were implemented across the Program. Ranging from 3 (13%) to 8 (13%) data layers (**Fig. 4**). The top two layers were NDVI from satellite, and yield maps, present in more than 65% of the case study reports. On the other hand, pH and composed topographic index (CTI) were less used and implemented by approximately 15% of the case studies.

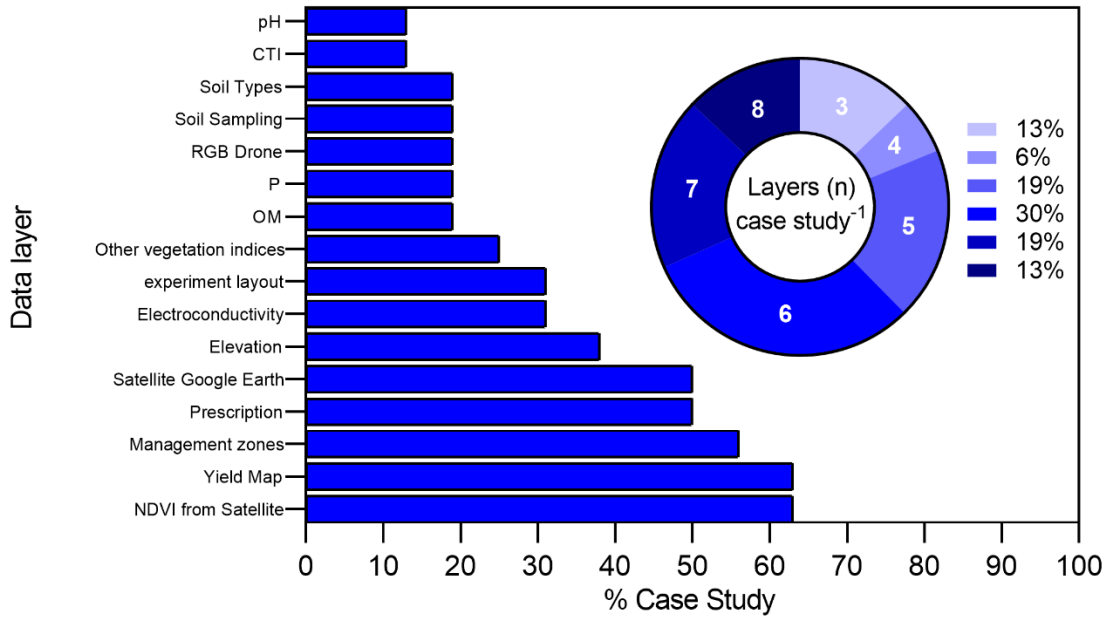

Figure 4. Percentage of case (blue bars) studies that included each data layer in their analysis. Pie chart represent the percentages of case study that used from 3 to 8 data layers. Color scale in pie chart represent numbers of data layers from lighter blue (3) to darker blue (8).

Survey results

To assess the overall perception of the students about the program, a survey was conducted five months after finishing the Diploma. HR survey included closed (**Fig. 5**) and opened (**Table 3**) questions. Responses showed that 75% of the students are currently applying in their professional activities the knowledge acquired in the Diploma Program. The case study approach implemented for the final project of the Diploma was considered highly useful by 81% of the students. The overall rate for the program's first cohort was 8.6 out of 10 (**Fig. 5**).

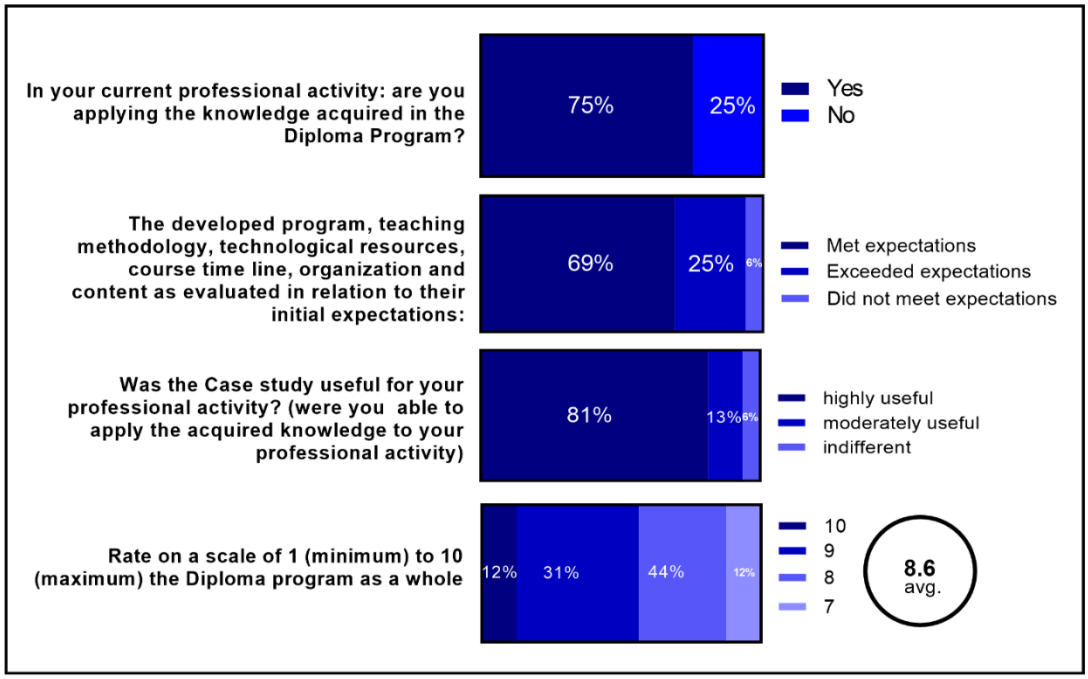

Figure 5. Results from the anonymous online survey with 16 students' responses (out of 32) conducted from April 20th to April 25th of 2022 regarding their appreciation of the Diploma Program.

Table 3. Selected responses from students to open questions in the anonymous online survey conducted from April 20th to April 25th of 2022 regarding their appreciation of the Diploma Program

Question:	Students' answers:
Which theoretical concepts did you understand or strengthen after completing the program?	"Trials statistical analysis", "Data analysis and spatial statistics", "geospatial statistical data management", design and analysis of experiments", "management zones delineation, economic analysis of precision ag implementation", "tele-detection and GIS", "maps processing", "spatial statistics".
Which practical procedures did you learn at DISAP and apply, or would you apply in your professional career?	"Use of fast mapping software and other statistical tools", "spatial analysis of field experiments", "principal component analysis, fertilization criteria, design and analysis of field experiments", "better use of QGis and statistical analysis", "field sonification, carbon footprint", "yield maps download and processing", "management zones generation and prescription maps"
Due to the restrictions due to the Covid 19 pandemic, all the development of the DISAP (except the presentation of the final work) was carried out virtually. What opinion do you deserve?	"The virtual program was good for students with limited time because of professional activities going on", "with the virtual program we were not required to travel, that usually complicates things", "… the program could be teach hybrid both in person and virtual", "been able to watch the recorded lecture was positive when we couldn't attend to the class", "Although I would have preferred face-to-face, it was very good given a lot of patience and dedication from the professors", "in my case virtual teaching was an advantage", "If it had not been virtual I do not know if I could have managed to complete the program", "virtual teaching was for me the path to be able to complete the program since I live far from the UNRC Campus", "The virtual program allows that people from all over the country can attend to the program", "I consider this an excellent opportunity for those who couldn't travel because we live far from the UNRC Campus, virtual classes are not the same but still we reached great interactions".
Based on your experience: What suggestion would you make for new	"More focus on spatial statistics", "more training activities", "deeper geo statistical concepts", "schedule classes out of working hours", "better distributions of the

DISAP cohorts?	courses seminars along the year", "extended deadlines to submit assignments", "expand on spatial data analysis and management zones delineation", "place a leveling course for GIS management before starting the program", "giving our poor background in statistics dedicate more time to this topic", "I will include more content on environmental impact, carbon footprint and pollution indices", "to continue with virtual program with some in person trainings", "include a UAV's course"

Fig. 6 Mr. Ohanian and Mr. Saleme (agronomists, graduated from the Program) presenting their Case study "Correlation between within field corn production variability and vegetation indices: NDVI, EVI and SAVI, in South of Córdoba" at the Second Latin American Congress of Precision Agriculture organized by the Latin-American Society of Precision Agriculture. Córdoba Argentina. March 2022.

Students were asked about the specific theoretical concepts and processing methods that they have learned in the Program. They agreed that new statistical concepts were acquired and applied in their data processing. Responses pointed out the relevance of learning how to process different data layers running geospatial analysis, to make a correct interpretation of the results. It was also mentioned the need to spend more time in these topics. Regarding the virtual teaching system, all of them agreed that this helped to finish the program since they spent less time traveling and they could organize their participation allowing them to keep working in their regular jobs. The need of in-person interaction was also mentioned for specific topics and to promote better interaction between students and professors. New topics were suggested to be incorporated in the next cohort, such as drone operation. Students mentioned that there is no other program offered covering these topics and these organizations with specialists covering each area of the PA program.

Conclusions

The University Diploma in Precision Agriculture offered by the National University of Río Cuarto is unique in Argentina, and has proven to be very useful to a wide audience, such as crop consultants and researchers.

The value-added of the training program was demonstrated by the 16 case-studies presented at the Second Latin American Congress of Precision Agriculture, in March 2022.

Educational efforts should continue to emphasize the specific needs of the significant players of precision agriculture: farmers, agribusiness, and educators, including new problem solving and operational skills.

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