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Profitability assessment of precision agriculture applications – a step forward in farm management

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Article

Profitability assessment of precision agriculture applications – a step forward in farm management

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Abstract. Profitability is an underestimated concept in precision agriculture. In this research, a new module is developed within a pre-existing farm management system to assess the profitability of precision agriculture applications in extended crops. The module is regulated on a 5-meter spatial resolution, thus allowing scaling up of original and processed data on a zone-, field-, cultivar-, and farm-scale. A bottom-up approach, taking advantage of the full functionality of the farm management system, together with a flexible architecture and an easy-to-use interface, renders the new module an innovative commercial application.

Keywords: precision agriculture; site-specific fertilization; ifarma; PreFer

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1. Introduction

1.1. The problem

The financial success of a business can be evaluated by its profit and profitability. Profit refers to the absolute measure of earnings minus the expenses involved in achieving a particular outcome. In a market-driven economic system, it is imperative for entrepreneurs to prioritize profit realization, as failure to do so compromises the sustainability and longevity of their enterprise [1]. Apart from maximizing profits, though, the goal of any agricultural enterprise is also to minimize costs.

Profitability represents a relative measure of a company's effectiveness, allowing for a comparison between the achieved outcome and the associated costs [2]. To ensure the profitability of an agricultural enterprise, efficient management is essential, typified by tasks such as soil tillage, crop planting, irrigation, weed management, pest, and disease control, and harvesting.

Further, effective farm management requires a combination of knowledge, skills, and experience, and often involves the use of technology and data-driven decision-making. The key lies in effectively utilizing production resources and adopting advanced techniques to produce crops [3]. It is crucial for businesses to prioritize maximizing their profits within the limitations of available resources, including financial and credit resources, material support for production, and the necessary skills to carry out the tasks of the workforce [4].

Precision Agriculture (PA) is one of several methodologies which can improve farm management by providing timely, thorough, site-specific crop information within a decision-making framework. Data can be retrieved from a variety of sources, such as soil sampling, sensors, weather stations, satellite or drone images, and yield monitors.

As a tool facilitating farmers to more efficiently manage their land, precision agriculture significantly and variously impacts farm management. According to global trends, the application of precision agriculture worldwide is estimated to increase in the next four years, with the market value doubling from 17.41 billion U.S. $ in 2022 to 34.1billion U.S. $ in 2026 [5].

The main goal of precision agriculture research is to define a decision support system (DSS) for whole farm management with the aim of optimizing returns on inputs while preserving resources

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[6–8]. However, farming is a complex endeavor involving many factors and inputs, such as land cost, labor, expensive machines and various tools, fertilizers, pesticides, and irrigation. In most cases, farming activities are not properly logged, at least not in a systematic and analytic way, while most data are fragmented, dispersed, and difficult to use [9].

According to a recent review based on 23-year meta-analysis [10], profitability, consultancy, and computer use had only a moderate effect on the adoption of precision agriculture. However, these findings should be viewed cautiously due to issues of sample size and heterogeneity embedded in some of the reference studies, while at the same time, other factors had a negligible effect on adoption. Precision agriculture must be discriminated from "smart agriculture", regarding the concept of site-specificity. Smart agriculture is associated with various types of sensors used (soil, moisture, climatic, etc.) to derive crop information (and potentially return a decision), regardless satisfaction of within-field spatial variability, as it happens with precision agriculture practices.

1.2. State of the art

Lately, several farm management platforms and technologies have become available to support precision and smart agriculture applications; below are some indicative platforms in English available in the market:

- Climate FieldView: An integrated digital platform that collects and analyzes field data, helping farmers make more informed decisions regarding crop management, planting, and harvesting. The available tools allow farmers to manually delineate management zones (https://www.fieldview.com.au/).
- Granular's Farm Management Software (FMS), credited as the first cloud-based, mobile-centric program of its kind, offers an intuitive breakdown of everything a farmer needs to consider, from financial to soil management to operations. The platform is mostly oriented to sensors and smart agriculture (https://www.corteva.com/resources/media-center/granular-provides-new-digital-nitrogen-management-options-to-farmers.html).
- Farmers Edge: A comprehensive smart agriculture platform that includes field-centric data collection, satellite imagery, variable rate technology, and weather analytics to optimize farm operations (https://farmersedge.ca/).
- Agworld: A collaborative farm management platform that allows farmers, agronomists, and other stakeholders to work together on planning, budgeting, and reporting of farm activities. It incorporates add-in applications for specific works (e.g. Satamap for satellite image display) (https://www.agworld.com/us/).
- Taranis: This platform uses artificial intelligence (AI)-driven image analysis, combining high-resolution aerial imagery and field-level weather data to detect and predict pest and disease issues, enabling farmers to make proactive decisions (https://www.taranis.com/).
- Trimble: A platform offering a range of precision agriculture solutions, mostly oriented to equipment and automation, including guidance and steering systems, flow and application control, yield monitoring, and water management tools (https://agriculture.trimble.com/en/products/software/trimble-agriculture-software).
- Sentera: A platform that integrates drone and satellite imagery with sensor data, enabling farmers to monitor plant health, track growth, and identify potential issues (https://sentera.com/).
- John Deere Operations Center: A web-based platform that helps farmers track equipment, manage field data, and analyze agronomic information to optimize their operations (https://operationscenter.deere.com/).
- Topcon Agriculture: A suite of visualization and decision-making tools including auto-steering systems, variable rate control, yield monitoring, and farm management software (https://tap.topconagriculture.com/).
- Raven Industries: Providing automations like guidance and steering systems, application controls, and field computers to help farmers optimize their operations (https://ravenind.com/).

Most of the above solutions -although quite technologically advanced- respond partially or even inadequately to the need for an integrated site-specific management. Moreover, economic records stored in the database (if they exist) are not always effectively linked to relevant precision farming data, or (even if they are), the platform leaves the user alone to carry out the analysis or make out the decisions. Therefore, in all cases there is a gap between available data, decision making on site-specific applications, and their economic evaluation.

To bridge this gap between farm management and precision agriculture applications, two Greek enterprises, Agrostis and Ecodevelopment, cooperated in 2022 to incorporate a site-specific fertilization service (namely PreFer) into a pre-existing Farm Management Information System (FMIS) (namely ifarma) [9].

ifarma was introduced to the Greek market in 2014 by Agrostis, as a cloud-based farm management information system (FMIS). The data model of ifarma integrates all information relevant to a farm, such as fields and land parcels, crops, farming activities on fields and inputs and resources used to plan and execute these activities. This data model organizes the information in a hierarchical manner, where the farm is at the top. Today, ifarma is a well-known trademark recognized as the best farm management software for agricultural holdings in Greece [11].

PreFer service developed by Ecodevelopment, produces prescription maps, which together with a variety of spatial layers (including soil properties, agronomic information, crop indices, statistical and predictive climatic parameters, and yield records) become available to the farmers on 5-meter spatial resolution on a regular basis. The prescription maps are created within a GIS, where big data are analyzed using machine learning methodologies [12].

1.3. Objectives

Going a step further, the objective of this research was to offer a complete and easy-to-use commercial solution for profitability assessment of precision agriculture applications in extended crops on an annual basis.

Accordingly, a new module was developed within the ifarma farm management platform using PreFer functionalities, especially its mapping environment and algorithms, thus facilitating interoperability, swiftness, and ease. In this respect, the next Section will present the materials and methods employed, Section 3 will demonstrate the results along with discussion and Section 4 will provide the main conclusions of this work.

2. Materials and Methods

2.1. System architecture

The new profitability module, namely, ProFit, is an independent module of the ifarma FMIS, in terms of interface and algorithms, although it cooperates with the PreFer module of ifarma, for exchanging map data. More specifically, ProFit takes spatial data from the PreFer database as input into its algorithms and returns output maps for display in the map viewer of PreFer. In this way, the original PreFer (say v.1) is upgraded into a new version (say v.2) after integrating with ProFit (Figure 1).

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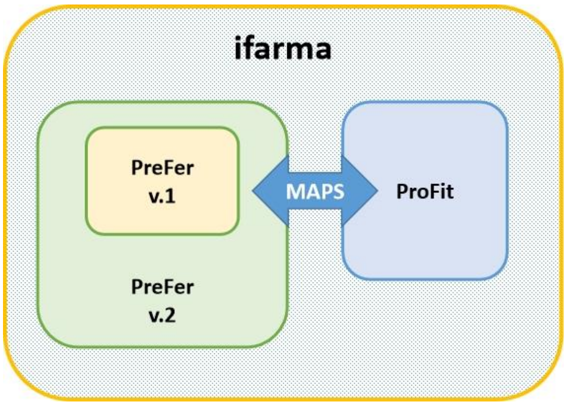

Figure 1. The architecture of ProFit, based on its conjunction with PreFer module of ifarma.

Going a step further, the objective of this research was to offer a complete and easy-to-use commercial solution for profitability assessment of precision agriculture applications in extended crops on an annual basis.

ProFit alone comprises two components (Figure 2). A site-specific cost component, which is fed by the database of PreFer, where the precision agriculture applications are stored and displayed. A shared cost component for other (non-precision agriculture) practices, where the required records are manually entered as lump sum amounts. The site-specific cost component takes input from two kinds of spatial data: a) the fertilizer application maps and b) the yield maps. The former is used to calculate fertilization cost at every surface unit (of 25 m^2) after the multiplication of the fertilizer's rates with its corresponding unit cost; the latter, meanwhile, are used to calculate earnings at every surface unit after the multiplication of the yield with the price of the corresponding cultivar in the market.

The shared cost component holds the lump sum amounts per expenditure category. The distribution of these lump sum costs is then based on an empirical classification of the fields of the farm according to a degree of difficulty (or weighting factor) on a categorical scale of 1-5, with '1' corresponding to the easiest field and '5' to the most difficult for each of the agriculture practices applied (e.g., soil tillage, irrigation, weed management, etc.).

The output data will be in two forms: a) descriptive statistics of cost, earnings, and profit per field; and b) profitability maps (cost, earnings, and profit maps) at a 25-m^2 surface unit. The calculations will be done automatically according to embedded formulas.

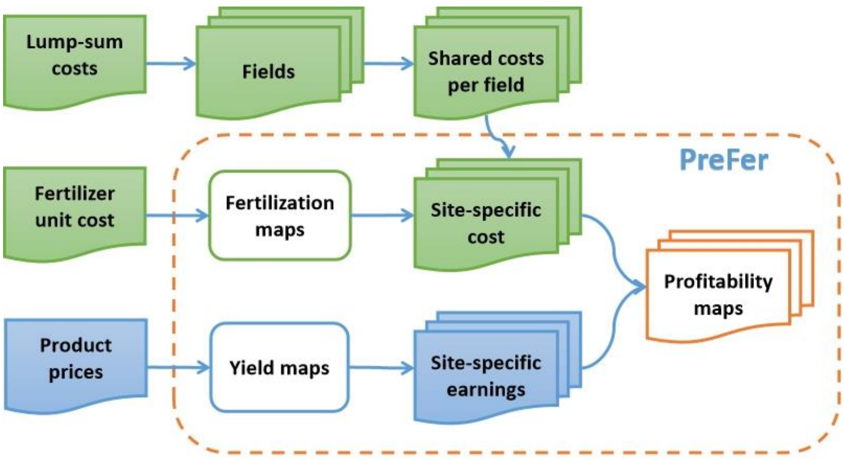

Figure 2. The structure of the profitability module in ifarma (partially functioning within the PreFer module).

2.2. Data requirements

The data entry of the shared cost records in ProFit is carried out manually through a new form which is divided into two sections, each corresponding to a number of agricultural practices. The site-specific data will be read from the maps stored in the PreFer database.

The shared cost data are related to total annual amounts for the entire cultivation and can be divided into the following categories (using a common ordering regardless change of category):

Section A (related to categorized total annual costs):

1. Land rent
2. Seeds
3. Irrigation
4. Fertilizers
5. Weed killers
6. Pesticides/Insecticides
7. Harvest
8. Machinery
    a) Depreciation
    b) Maintenance
    c) Spare parts

Section B (related to total annual costs per field):

9. Land rent (absolute amounts)
10. Degree of difficulty per field for shared cost (weighting factor: 1-5)
    d) Seeds
    e) Irrigation
    f) Fertilizers
    g) Weed killers
    h) Pesticides/Insecticides
    i) Harvest
    j) Machinery

2.3. Algorithms developed

A set of interrelated functions have been setup for ProFit, which carry out arithmetic, categorical, and logical operations, and transfers of tabular data. The overall arrangement is integrated and executed in a prototype Excel spreadsheet, where all internal functions and options and the external data feed are arranged. The monetary rate unit is set to euros per hectare (€/ha), the fertilizer amounts in kilograms per hectare (kg/ha), and the yield in tonnes per hectare (t/ha) (Figure 3).

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SHARED COST			CATEGORIES	[2] SEEDS	[3] IRRIGATION	[4] FERTILIZERS	[5] WEED KILLERS	[6] PESTICIDES & INSECTICIDES	[7] HARVEST	[8] EQUIPEMENT DEPRECIATION	[9] EQUIPEMENT MAINTENANCE	[10] FUELS	[11] LABOUR	TOTAL COST (€)
			ANNUAL TOTALS (€)	460	3,392	9,162	2,925	542	10,033	2,950	740	3,312	1,670	51,013
FIELDS	CULTIVARS	SURFACE (ha)	[1] LAND RENT (€/ha)	RATE OF DIFFICULTY										
006	CL 111	3.79	950	1	1	2	5	3	1	2	1	1	1	
007	CL 111	3.75	1,010	1	1	2	1	2	1	2	1	2	1	
008	RONALDO	4.37	1,100	2	1	1	3	1	1	1	1	2	2	
009	RONALDO	5.05	1,050	2	1	1	2	1	1	1	1	4	1	
TOTAL SURFACE		16.96	AVERAGE UNIT COST (€)	27	200	540	172	32	592	174	44	195	98	
NUMBER OF FIELDS		4		TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	

SITE-SPECIFIC COST		
FERTILIZERS	UNIT COST (€/kg)	COST (€/kg)
ALZON	1.00	6,610
TSP	0.73	855
K2SHO4	0.85	1,697
N40	0.78	3,043
	TOTAL	9,162
TRUE	AVERAGE	540

BALANCE SHEET PER FIELD				AMOUNTS (€)													
FIELDS	CULTIVARS	SURFACE (ha)	[1] RENT COST (€)	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	TOTAL COST (€)	UNIT COST (€/ha)	EARNINGS (€)	PROFIT €)
006	CL 111	3.79	3,601	66	758	2,835	1,207	218	2,242	913	165	312	297	12,613	3,328	20,193	7,580
007	CL 111	3.75	3,788	65	750	2,805	239	144	2,218	903	164	617	294	11,986	3,196	19,800	7,814
008	RONALDO	4.37	4,807	152	874	1,634	835	84	2,585	526	191	720	684	13,092	2,996	27,610	14,517
009	RONALDO	5.05	5,303	176	1,010	1,888	643	97	2,987	608	220	1,663	395	14,991	2,969	32,724	17,733
TOTALS		16.96	17,498	460	3,392	9,162	2,925	542	10,033	2,950	740	3,312	1,670	52,683		100,327	47,644
AVERAGE		4.24	1,032	27.1	200.0	540.2	172.5	32.0	591.5	173.9	43.6	195.3	0.1	FALSE	3,106	TRUE	47.5%
																	PROTIT RATIO

BALANCE SHEET PER CULTIVAR								
FIELDS	CULTIVARS	SURFACE (ha)	PRICE (€/kg)	MEAN YIELD PER CULTIVAR (t/ha)	INCOME (€)	COST (€)	PROFIT (€)	UNIT PROFIT (€/ha)
006 & 007	CL 111	7.54	0.48	11.1	39,993	24,599	15,394	2,042
008 & 009	RONALDO	9.42	0.54	11.9	60,334	28,084	32,250	3,424
TOTALS					100,327	52,683	47,644	2,809

TOTAL	53,749
/ha	3,169

INPUT	
OUTPUT	

SITE-SPECIFIC DATA INPUT (MAPS)

FERTILIZATION MAPS			
FIELD	FERTILIZERS	MEAN APPLIED UNIT (kg/ha)	TOTAL APPLIED AMOUNT (kg)
006	ALZON	390	1,478
006	TSP	81	307
006	K2SHO4	150	569
006	N40	230	872
007	ALZON	390	1,463
007	TSP	59	221
007	K2SHO4	127	476
007	N40	230	863
008	ALZON	389	1,700
008	TSP	58	253
008	K2SHO4	100	437
008	N40	230	1,005
009	ALZON	390	1,970
009	TSP	77	389
009	K2SHO4	102	515
009	N40	230	1,162
	OVERALL	806	13,678

FERTILIZERS	TOTAL APPLIED AMOUNT (kg)	MEAN APPLIED UNIT (kg/ha)
ALZON	6,610	390
TSP	1,171	69
K2SHO4	1,997	118
N40	3,901	230
TOTAL	13,678	TRUE

YIELD MAPS			
FIELD	CULTIVAR	MEAN YIELD (t/ha)	TOTAL YIELD (t)
006	CL 111	11.1	42.1
007	CL 111	11.0	41.3
008	RONALDO	11.7	51.1
009	RONALDO	12.0	60.6
	OVERALL	11.5	195.0

SUBSIDIES		
	€/ha	€
GREENING	300	5,088
RIGHTS	60	1,018
	TOTAL	6,106

Figure 3. The prototype spreadsheet of ProFit algorithm, filled with true data from the 2022 cultivation year (4 indicative fields).

The basic formula for cost, earnings, and profit calculations applied per field, is shown simplified below:

Cost =
Field Rental Cost +
Field Shared Cost for Agricultural Practice [1] +
Field Shared Cost for Agricultural Practice [2] +
Field Shared Cost for Agricultural Practice [3] +
…
Field Shared Cost for Agricultural Practice [8c] +
Quantity of Fertilizer-1 [Input from the Fertilization Maps of PreFer database] x Price of Fertilizer-1 (manual input in relevant table) +
… (as many times as the number of fertilizers, n)
Quantity of Fertilizer-n [Input from the Fertilization Maps of PreFer database] x Price of Fertilizer-1 (manual input in relevant table)
Earnings = Yield (t/ha) [Input From the Yield Map] x Cultivar Price (monetary unit/kg) [Input from the Crop List]
Profit = Earnings – Cost

For splitting the shared cost lump sums of the different agricultural work categories into cost items per field, a stepwise procedure is followed (Figure 4):

1. First, the rate of difficulty of each field is multiplied by the field's extent and then divided by the number of fields under consideration, to give a weighted rate of difficulty.
2. Then, the weighted rate of difficulty of each field is divided by the total weighted rate of difficulty to give the cost share for the field (for each of the shared cost categories).
3. Finally, the cost share of every field is multiplied by the total cost of the category and divided by the number of fields to give the absolute cost per field (for that cost category).

Therefore, for every category, the algorithm retrieves the lump sum amount for the entire cultivation from a manually filled table and the field extents from the farm's geodatabase (i.e. from PreFer). Thus, the only inputs required by the algorithm are the rates of difficulty per field and for each work category. An internal control function will check if the earlier entered lump sum for the working cost category is equal to the one calculated by the algorithm.

Total cost of work (€)	2,925						
FIELDS	SURFACE (ha)	Rate of difficulty (1-5)	Weighted rate	Cost share	Cost per field (€)	Unit field cost (€)	Relative cost
006	3.79	5	4.7	1.65	1207	318.6	184.7%
007	3.75	1	0.9	0.33	239	63.7	36.9%
008	4.37	3	3.3	1.14	835	191.1	110.8%
009	5.05	2	2.5	0.88	643		
Totals	16.96		2.9	1.00	2,925		
Number of fields	4			Control	TRUE		
Average unit cost (€)	172.5						

Figure 4. An example of the cost lump sum splitting algorithm (prototype) (same dataset as Figure 3).

3. Results and Discussion

3.1. System functionality

The new module ProFit comprises a spatial and a non-spatial component. The spatial component is developed in the pre-existing module PreFer within the ifarma FMIS. As a result, the output maps of ProFit follow the same standards as that of the PreFer module, i.e., a spatial resolution of 5 meters (surface unit of 25 m^2) and a classification of the original values into 7 categories.

The non-spatial components include output tables which at the same time contain the entire input information. Thus, the user gets the whole economic picture of the cultivation in a single tabular arrangement.

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3.2. System interface

The ProFit module is available as an option in the main menu of the ifarma interface, specifically in the 'Management of works, inputs, and yields' group (currently only in Greek). By clicking the ProFit button (set below the 'PreFer' option), the input form for entering values for the required economic items is launched in a single web page (Figure 5). For convenience, the output fields are displayed in a different form after the execution of the calculations and can be exported to spreadsheets.

Apart from the tabular output data (e.g., statistics per field and the entire cultivation), which are displayed on a different web page of the ifarma environment, the output maps are displayed within the PreFer map viewer. The options for displaying the cost, earnings, and profit maps for every cultivation are available inside the 'Performance' group of options in the PreFer map viewer menu (which also includes the yield maps).

3.3. Experiences

Most of the existing platforms in the market are top-down, originating from the need of an already established market player to promote its products, services, or goods through the concepts of precision agriculture. In most cases, these platforms provide financial management as a parallel service to another main service, e.g., fleet management, crop calendar, etc.

Conversely, ProFit on ifarma follows a bottom-up approach, starting from the applications and considering all the farming details to conduct a thorough economic analysis, while enabling spatially distributed outputs in terms of maps.

The development team was assisted significantly by several farmers who implemented precision agriculture over the course of years, through their ideas and experience and by using and testing the module with authentic farming data from the 2022 cultivation year in Greece.

Using real data combined with some notional options, for example, in the selection of the difficulty factors per field, to test the module under extreme data ranges it was noticed that yield maps might be quite different from profitability maps (especially between fields) (Figure 6).

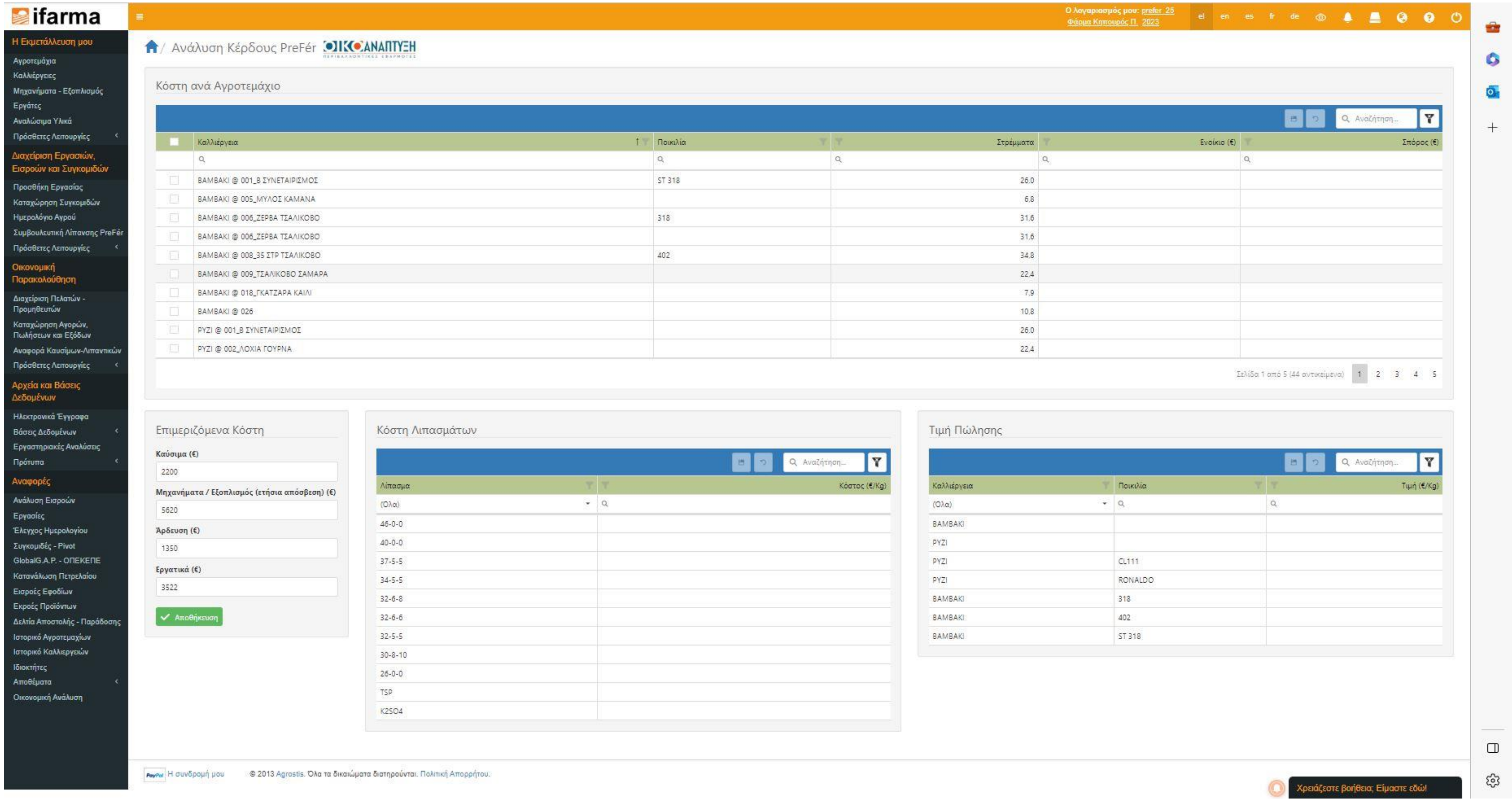

Figure 5. The input form for the required data for profitability assessment by ProFit (ifarma interface).

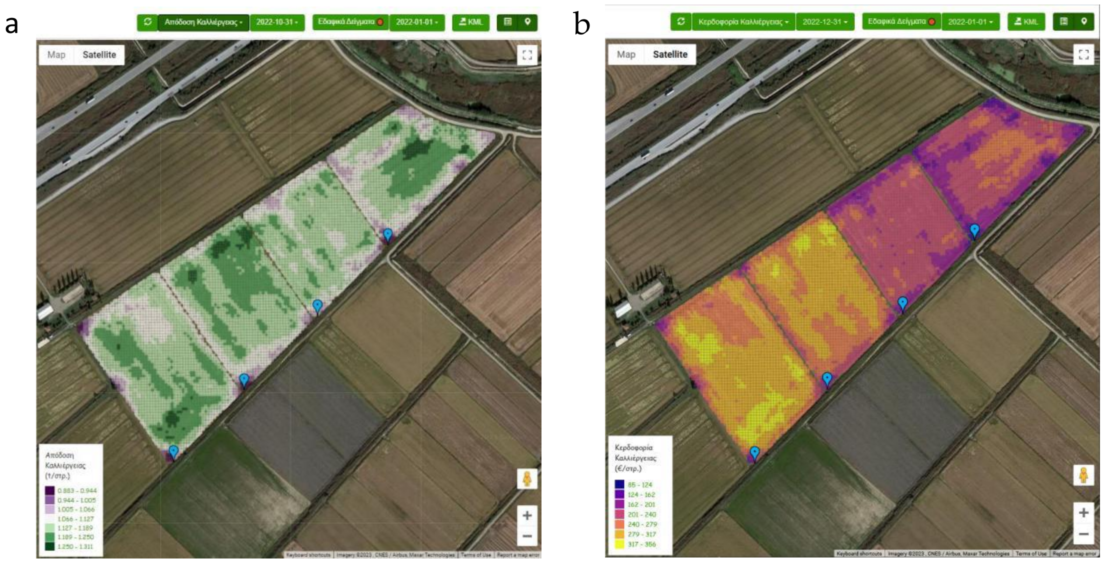

Figure 6. An example of yield vs. profit map of the same fields and year in the ifarma/ProFit environment (example of Mr. Kostas Kravvas rice farm, Greece).

5. Conclusions

In this research, an innovative module for assessing the profitability of precision agriculture applications was developed, namely ProFit. In terms of architecture, ProFit is embedded within a cloud-based farm management information system, namely “ifarma”, while taking advantage of pre-existing functionalities, such as a precision agriculture database provided by other ifarma modules, like PreFer.

ProFit offers an easy-to-use interface, which encourages farmers to enter economic records quickly and reliably, while using an empirical method to share apportionable expenditures between fields (when and where site-specific maps are not available). At the same time, it uses the map view environment of PreFer to display the profitability maps.

Future work will focus on widening the range of precision agriculture practices (I.e., beyond fertilization) within ProFit, such as soil tillage, seeding, irrigation, weed management, and crop protection.

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References

1. Barkley, A.; Barkley, P. W. *Principles of Agricultural Economics*, 1st ed.; Routledge: Abingdon-London, United Kingdom, 2013, pp. 1-384. DOI: https://doi.org/10.4324/9780203371145
2. Epifanova, I. Y.; Humeniuk, V. S. Profitability of the enterprise: modern approaches to defining the essence. *Econ Soc* **2016**, *3*, 189-192.

3. Smoliy, L.V. Formation of the results of economic activity of Agricultural Enterprises. *Collected Works of Uman National University of Horticulture* **2019**, *95*(2), 115-128. DOI: 10.31395/2415-8240-2019-95-2-115-128
4. Shmatkovska, T. O.; Dziamulych, M.; Vavdiiuk, N.; Petrukha, S.; Koretska, N.; Bilochenko, A. Trends and Conditions for the Formation of Profitability of Agricultural Enterprises: A Case Study of Lviv Region, Ukraine. *Univers. J. Agric. Res.* **2022**, *10*(1), 88–98. DOI: https://doi.org/10.13189/ujar.2022.100108
5. Shahbandeh, M. Smart Agriculture: Market Size Worldwide 2026. https://www.statista.com/statistics/720062/market-value-smart-agriculture-worldwide/ (accessed on 20/04/2023).
6. McBratney, A. B.; Whelan, B.; Ancev, T.; Bouma, J. Future Directions of Precision Agriculture. *Precis. Agric.* **2005**, *6*(1), 7–23. DOI: https://doi.org/10.1007/s11119-005-0681-8
7. Whelan, B.; McBratney, A. B. Definition and interpretation of potential management zones in Australia. Solutions for a Better Environment. In Proceedings of the 11th Australian Agronomy Conference, Geelong, Victoria, Australia, 2-6 February 2003, 0–11.
8. Singh, P.; Pandey, P. C.; Petropoulos, G. P.; Pavlides, A.; Srivastava, P. K.; Koutsias, N.; Deng, K. A. K.; Bao, Y. Hyperspectral remote sensing in precision agriculture: present status, challenges, and future trends. In *Earth Observation, Hyperspectral Remote Sensing*, Pandey, P. C.; Srivastava, P. K.; Balzter, H.; Bhattacharya, B.; Petropoulos, G. P.; Elsevier eBooks, 2020, pp. 121–146. https://doi.org/10.1016/B978-0-08-102894-0.00009-7
9. Karydas, C. G.; Chatziantoniou, M.; Stamkopoulos, K.; Iatrou, M.; Vassiliadis, V.; Mourelatos, S. Embedding a precision agriculture service into a farm management information system- ifarma/PreFer. *Smart Agric. Technol.* **2023**, *4*, 100175. DOI: https://doi.org/10.1016/j.atech.2023.100175
10. Tey, Y.S.; Brindal, M. A meta-analysis of factors driving the adoption of precision agriculture. *Precis. Agric.* **2022**, *23*, 353–372. DOI: https://doi.org/10.1007/s11119-021-09840-9
11. Paraforos, D.S.; Vassiliadis, V.; Kortenbruck, D.; Stamkopoulos, K.; Ziogas, V.; Sapounas, A. A.; Griepentrog, H.W. Multi-level automation of farm management information systems. *Comput. Electron. Agric*. **2017**, *142*, 504–514, DOI: https://doi.org/10.1016/j.compag.2017.11.022
12. Iatrou, M.; Karydas, C.; Tseni, X.; Mourelatos, S. Representation Learning with a Variational Autoencoder for Predicting Nitrogen Requirement in Rice. *Remote Sens*. **2022**, *14*, 5978. DOI: https://doi.org/10.3390/rs14235978