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EMPOWERING LIVES
THROUGH KNOWLEDGE
AND IMAGINATION

Bocconi School of Management

MILANO I ITALY

A STUDY CASE ON PRECISION FARMING: VITICULTURE

Vitaliano Fiorillo, Director AGRI Lab
Mattia Pianorsi, Senior Research Fellow SEE Lab

SDA Bocconi School of Management | AGRI Lab Romeo ed Enrica Invernizzi Agribusiness Research Initiative

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01 PRECISION VITICULTURE

02 EMPIRICAL RESEARCH

03 OUR PERSPECTIVE AND CONCLUSIONS

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VITICULTURE

In viticulture, it occurs frequently that the **same vineyard**, especially when particularly extended, is characterized by **different small units** that differ for soil, morphology, and microclimate and therefore needs to be managed in different and specific ways.

In other words, it is very common to have a **variable productivity** within the same vineyard or even along the same row.

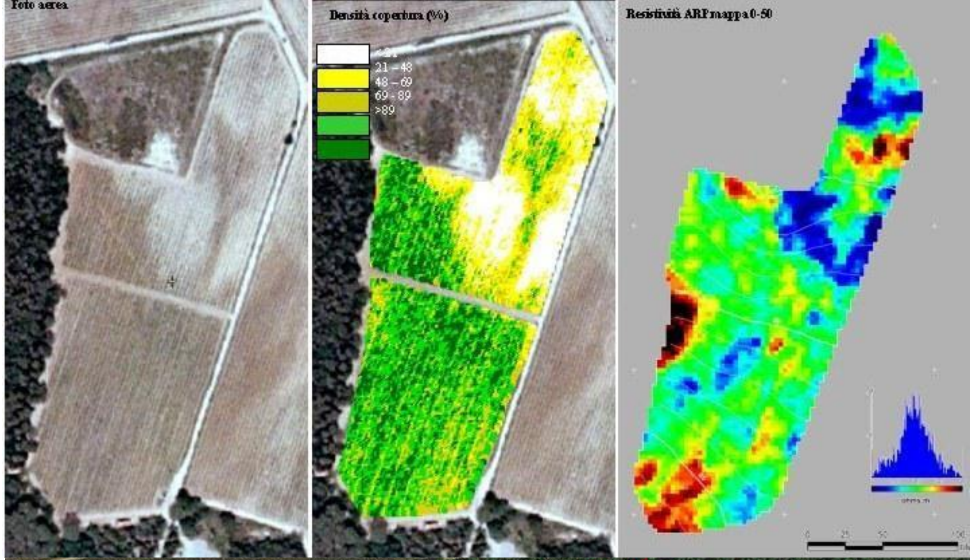
Until a few years ago, the only way to approximately determine soil and plants needs was through **sampling analysis**, with obvious variability in results and **poor data granularity in spatial terms**.

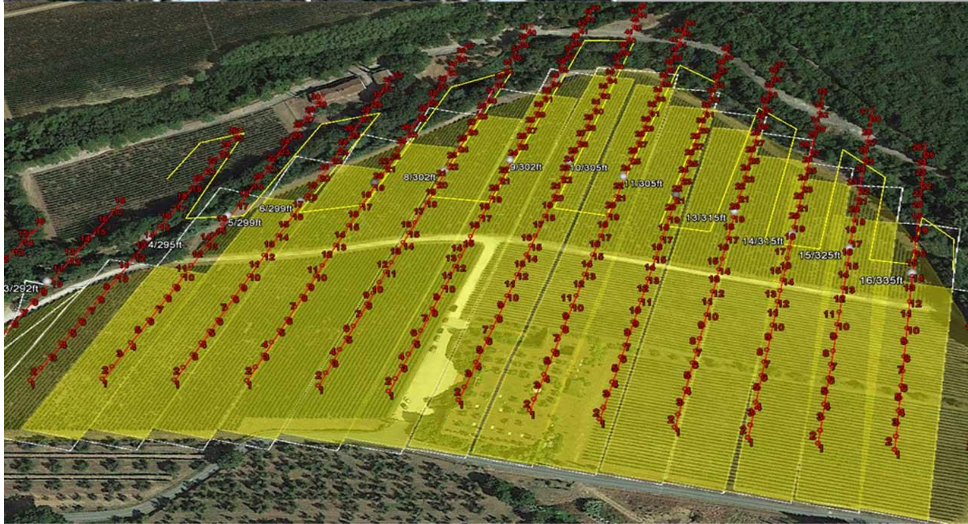
PRECISION VITICULTURE

The goal of **precision viticulture** is to identify the precise status, health condition, vigor, and physiological needs of each unit of vines and to adapt accordingly the crop techniques to implement. As a result, the introduction of precision viticulture methodologies **allows the efficiency and quality of the production** to be improved and reduce the environmental impact.

The rapid evolution of information communication technologies and geographical science offers enormous potential for the development of optimized solutions for distributed information for precision viticulture. Specifically, remote sensing technologies allow useful information to be collected and elaborated.

Among the many technologies applied in viticulture, both on the field and in transformation process, **remote sensing technologies such as drones, and satellites** have demonstrated to be particularly suitable for precision viticulture.





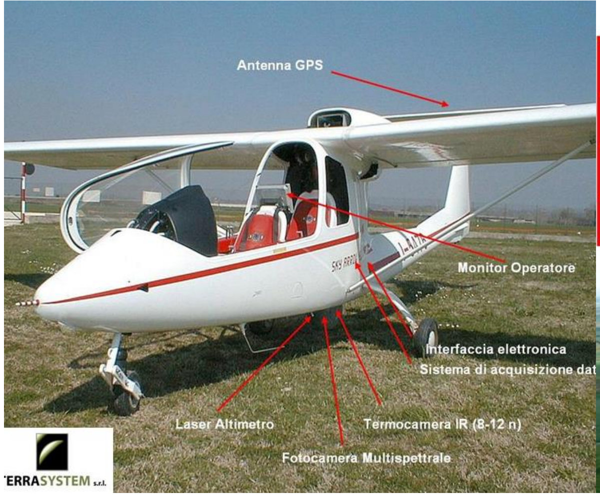
HOW DOES IT WORK?

A satellite or an aircraft take **imagery of the vineyards** through a special **multispectral imaging camera**. For each pixel, the **intensity of solar light reflection from vegetation is detected** by means of hyperspectral sensors.

The percentage of incident radiant energy that is reflected by vines and subsequently detected by these technological devices defines the **reflectance of the different surface units**. This reflectance is strongly sensitive to **chlorophyll** content. Depending on the wavelength of the incident electromagnetic radiation, **chlorophyll reflects different colors** – green, red, and yellow – that will appear in the multispectral imagery **showing the health and vigor of the plants**.

The information is sent to geo-databases and processed with geostatistical techniques, describing plant status and the management approaches to be applied to each micro-area. **All the data collected are geo-localized** (GPS).

Once transferred and processed, the **data can be transmitted directly to tractors**.



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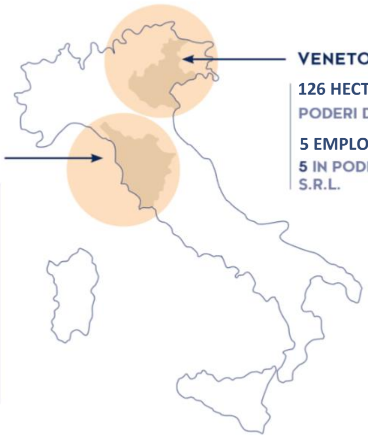
RUFFINO

RUFFINO
A CONSTELLATION BRANDS COMPANY



VENETO
126 HECTARES:
PODERI DUCALI S.R.L.*
5 EMPLOYEES:
5 IN PODERI DUCALI S.R.L.

TOSCANA
413 HECTARES:
LA SOLATIA
GREPPONE MAZZI
GRETOLE
MONTEMASSO
POGGIO CASCIANO
SANTEDAME
203 EMPLOYEES:
133 IN RUFFINO S.R.L.
70 IN TENUTE RUFFINO S.R.L.

OUTPUT VALUE	€ 103.822.001
MARKETS	USA, Canada, EMEA, Rest of the World (85 markets)

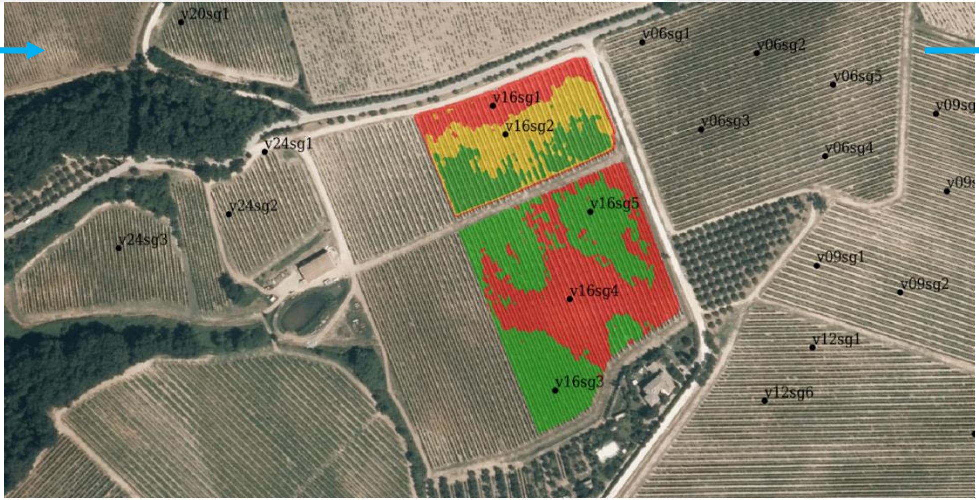
CERTIFICATIONS AND AWARDS:

IFS Food	DNV·GL ISO 9001	biodiversity friend	DNV·GL ISO 14001	Award
RUFFINO	RUFFINO	RUFFINO E TENUTE RUFFINO	RUFFINO E TENUTE RUFFINO	RUFFINO E TENUTE RUFFINO

FROM IMAGES TO MANAGEMENT

APPLICATION
Site-specific

OBSERVATION
Remote-proximal sensing

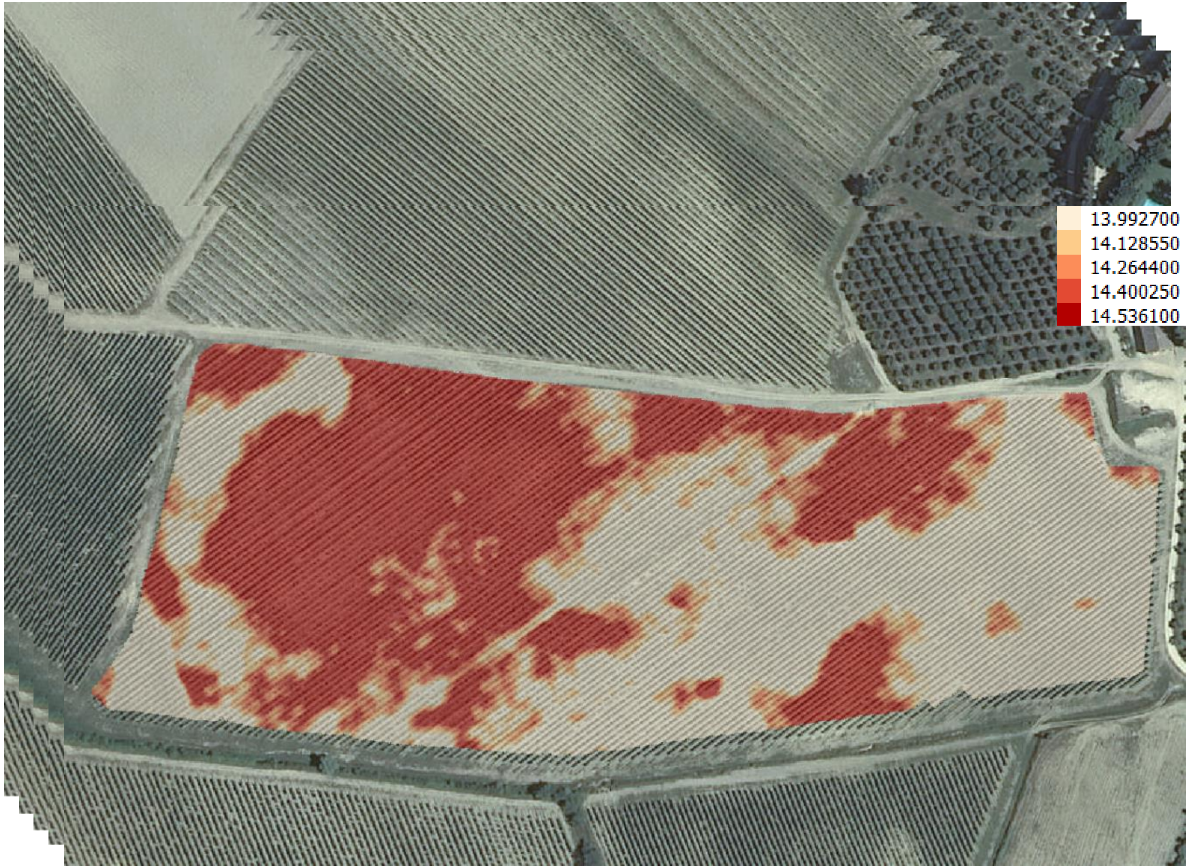


PLANNING
Strategy
Prescriptive maps

EXPERT
AGRONOMIST

ASSESSMENT
Sampling
Derived maps

HARVEST STRATEGY 2014-2015



HARVEST POSTPONED

- 26/09
- 07/10

SITE SPECIFIC MANAGEMENT

- Green manure
- VRT fertilization
- Early leaf removal

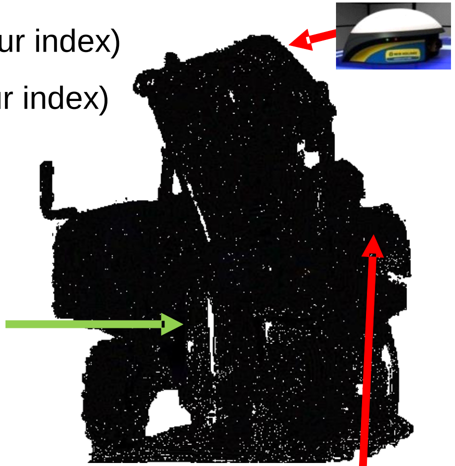
2015

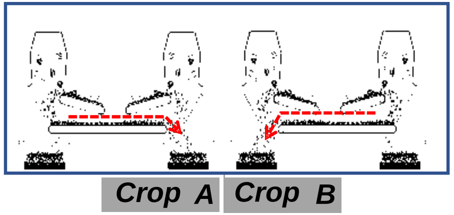
- Productive homogeneity
- Standard mechanized harvesting

SELECTIVE HARVESTING

- Quality A (high vigour index)
- Quality B (low vigour index)

Antenna NH162





Transversal conveyor
Carry over from GE

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OUR PURPOSE

The firm's objective of applying the set of different enabling precision technologies to the production of grapes is to

- **Manage grape quality** and yield maps that are of great importance during the harvest to avoid mixing grapes of different potential wine qualities;
- **Increase profitability** of agricultural operations with the acquisition of reliable site-specific information that allow the reduction of costs through the **optimization of inputs** (fertilizers, fuel, and labor).

The **cost-effective management** of agricultural assets represent the **hypothesis that the analysis aims to verify**.
The **model** applied to assess the impact of technologies on the business is the **total cost function**, which is **estimated** through the method of **multiple regression analysis**.

GENERAL MODEL

Considering a generic total cost function *C=f(Q,P,T),* we applied the translog cost function which is a second order approximation to a cost function.

A general translog cost function specification with a provision for non-neutral technological change is given by:

$$\ln(\mathrm{C}) = f(\ln Q, \ln P, \ln T)$$

Where

C = total costs

Q = Output

P = Price of factors

T = Technology

The translog cost function models the relationships among

- firm costs and
- firm output, input prices, and technology including the **interaction terms** involving the **explanatory cost factors**.

Relevant for the analysis is how the **costs change** due to the **application of precision technologies** and its interaction with the factors that cause cost incurrences.

In the linear empirical specification, however we estimated a **form of the translog** cost function that only encompasses, as interaction terms, output and technology due to the shortage of the available data.

ESTIMATION

The estimation of the **specified translog cost function** relies on the method of **multiple regression analysis**. It is an approach to **modeling the relationship between a dependent variable and independent variables**.

To perform the multiple regression analysis, we collected observations of three vineyard estates for a seven years' period (2012-2018). Below, is summarized the set of variables (21 observations) used in the estimation:

Dependent variable:
- Total costs on total grapes produced per vineyard estate (Ct)

Output:
- High-quality grapes on total grapes produced per vineyard estate (Q)

Input prices:
- Production costs on total grapes produced per vineyard estate (P_k)
- Personnel costs on total grapes produced per vineyard estate (P_l)

Applying the multiple regression method to the specified translog cost function results in:

$$\ln(C_t) = \beta_0 + \beta_1 \ln(\mathrm{Q}) + \beta_2 \ln(P_k) + \beta_3 \ln(P_l) + \beta_4 (Z) + \gamma_1 \ln(Q)(Z) + \mu$$

Where
- C_t is the dependent variable
- Q, P_k, P_l are the explanatory variables
- β_0 is a constant term
- β_n are fixed coefficients that express the marginal contribution of each independent variable to C_t
- γ is a fixed coefficient expressing the effects on the dependent variable (the cost) through the effects of one explanatory variable (the technology) on a second independent variable (the quantity);
- Z is a **dummy variable** included in the model to represent **the technology change**. The dummy assumes the value 0 or 1 to indicate the absence or the presence of the technological change;
- μ is the sum of unspecified factors, the errors.

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RESULTS

With a statistical significance level at **α= 0.05**, the estimated coefficient of the equation are:

$$\ln(C_t) = \mathbf{0.7054} + \mathbf{0.0067}\ln(Q) + \mathbf{0.5661}\ln(P_k) + \mathbf{0.4559}\ln(P_l) - \mathbf{0.0253}(Z) - \mathbf{0.0393}\ln(Q)(Z)$$

Where Z = 0 if the precision technologies are not included
1 if the precision technologies are included

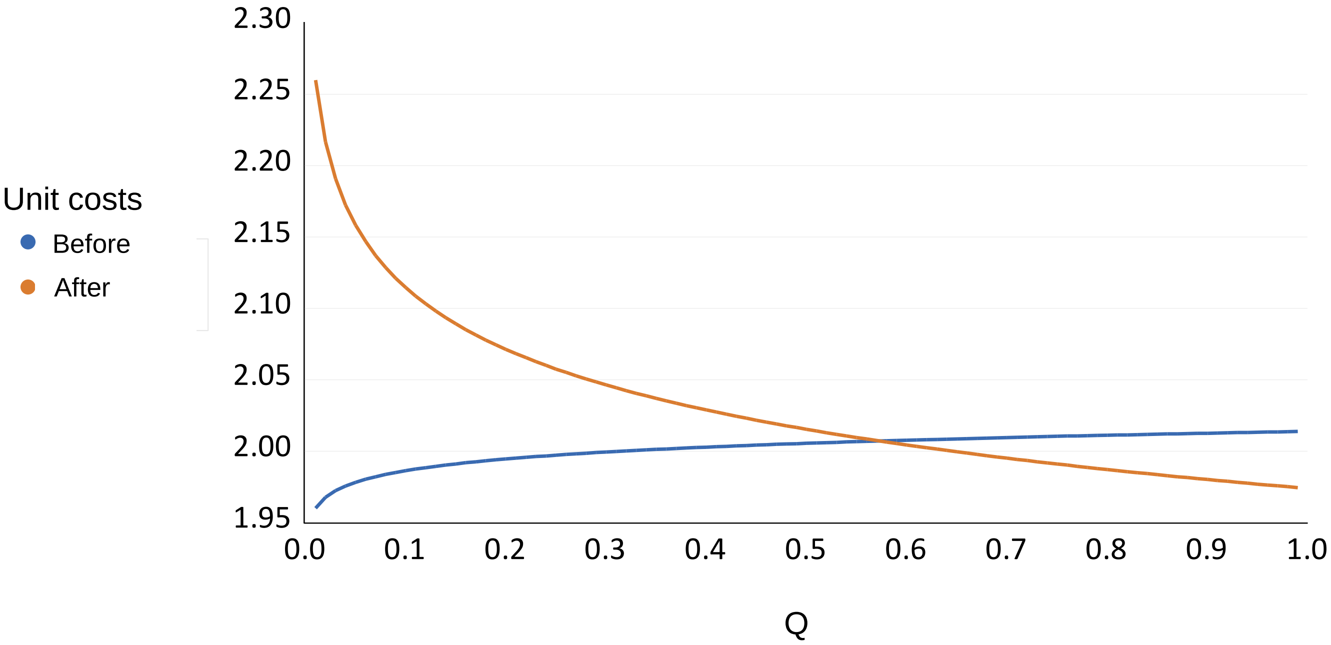
Ct	Coef.	Robust Std. Error	t	P > I t I	[95% Conf. Interval]	
Q	0.0067394	0.0025854	2.61	0.020	0.0012287	0.01225
P_k	0.5661539	0.0176671	32.05	0.000	0.5284973	0.6038105
P_l	0.4559267	0.0145736	31.28	0.000	0.4248638	0.4869869
Z	- 0.0253902	0.0103802	-2.45	0.027	-0.0475151	-0.0032656
QZ	- 0.0393271	0.0125629	-3.13	0.007	0.0661042	-0.01255
Cons	0.7054832	0.0035468	198.91	0.000	0.697935	0.713043

Number of obs	21
F (5,15)	2761.79
Prob > F	0.0000
R-squared	0.9986
Root MSE	0.01758

- The estimated coefficients of the independent variables **are statistically significant** with a *P-value* smaller that 5%;
- **Before** the introduction of precision technologies (dummy=0), there is a positive correlation between the share of high-quality grapes produced (Q) and the unit costs (C) identified by the coefficient β1 (=0.0067);
- **After** the introduction of precision technologies (dummy=1), there are two major implications:
  - The **fixed costs of the firm decrease**: the intercept changes due to the decremental effect of the dummy variable coefficient (β0 + β4);
  - An increase of the share of high-quality grapes production results in a reduction of the unit costs of the firms due to the **optimization of inputs** (variable costs). It highlights a negative correlation between the share of high-quality grapes produced (Q) and the unit costs (C) : the slope of the curve changes assuming a negative inclination (β1 + γ1).

RESULTS

Unit costs of the firm, before and after the use of the set of precision viticulture technologies (under the assumption of keeping constant the price of inputs)



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FINAL REMARKS

- The tendency is that the employment of precision viticulture technologies suggests positive economic impacts on the business in terms of optimization of inputs affecting both fixed and variable costs;
- Generally, the benefits and the use of precision viticulture technologies should be weighted to the level of organizational structure of end-users:
  - More structured wineries (large companies), with qualified personnel and production processes guided by efficiency and mechanization, could use the technology as complementary resource to ensure high quality standards of grapes (major scope);
  - Less structures wineries (small-medium firms) could instead invest in precision technologies to definitively take advantage of a cost-effective management of agricultural assets (major scope).
- In our opinion, the challenge is to enable small-medium wineries to benefit from precision viticulture innovations which, as an integrated system of more technologies (spatial images, proximity sensors, automated tractors, …) require demanding investments. Supporting schemes might include:
  - A standardized and cost-effective offer from satellite service providers;
  - Small-medium producers organized in consortia acting as an unique customer;
  - Public incentives to sustain the investments in fixed assets.
- More detailed investigations will be carried out to confirm the impact of precision technologies on profitability including a sample of heterogeneous viticulture firms with different economics.

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THANK YOU FOR YOUR ATTENTION

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