SUMMARY AND REMARKS - SESSION 3: Specific mechanization: machines for viticulture.

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1. Introduction

Nowadays, the agriculture equation must concurrently balance crop profitability and human and environmental safety. Any improvement to viticulture mechanization can potentially contribute to sustainability reducing environmental and human contamination risk, raise food quality and safety standard, enhancing at the same time productivity and profitability of vineyards. The adoption of innovative precision viticulture technologies, at farm level, will be even more strategic to comply with the European Union Green Deal that within the Farm to Fork Strategy strives to i) reduce the pesticide inputs of 50%, ii) reduce nutrient losses of 50%, concurrently reducing fertilizers inputs of 20%, and iii) increase of 25% the organically farmed land by 2030.

The Club of Bologna (CoB) draw the focus on specific mechanizations for viticulture discussing in a dedicated session the current situation of mechanization in the viticulture sector and its perspectives for the future with particular attention to the sustainability of viticulture. This report introduces and summarizes three speaker presentations and overall remarks/key sentences provided by CoB participants to the third session.

An introduction analysing the **present situation and perspectives of viticulture in the world** was given by Osvaldo Failla, Professor of arboriculture and Fruit Tree Growing at University of Milan (Italy). Afterwards, Emilio Gil, Professor of Department of Agri-Food Engineering and Biotechnology (Polytechnic University of Catalunya – Spain), reports about the **most advanced technologies for precise viticulture** already available and the drivers for future innovative research topics in the ambit of precision viticulture. Finally, Eng. Thierry Le Briquer., Grape, Olive and Coffee product Line Director for CNH Industrials, provides a focus on **grapes mechanical harvesting** analysing the status and future perspectives for the productivity and quality production enhancement.

2. Presentation 1 - Viticulture in the world: present situation and perspectives (Osvaldo Failla, University of Milan, Italy).

Even if the world vineyard cropped surface represents only the 0.5% (7.4 million ha) of total world cropped land. When it is referred to the permanent cropped area (olive, citrus, grapes, orchards, etc.) vineyards represent a considerable surface extension equal to 4.3%. Furthermore, the vineyard cropped surfaces are mainly concentrated in the temperate area of the world with few countries, Spain, China, France, Italy and Turkey, representing more than 50% to total world vineyard surface. In the last two decades the trend of total world vineyard cropped surface observed a decrease rate from 2000 to 2010 while from 2011 to date the surface was maintained constant even if the trend in different countries shows opposite behaviour. In general, in European countries, especially in Spain, Italy and France, the surface decreased a lot, and it is still decreasing while in China and Russia it increased rapidly and considerably. An opposite trend is showed by the grapes yield that showed in the last two decades a consistent increase in four steps over the years; the grape yield increase can be attributable i) to the consistent increase of table grapes vineyard especially in China and India, ii) to the improvement of existing vineyard performances and iii) to the increasing of cropped vineyard surfaces in flat areas instead of troubling hilly areas. It derives that in 2018 the 72% of total grape yield was devoted to wine production, 27% to the table grape and 1% to the dried grape (Figure 1).

The trend of vineyard cropped surfaces and yield in Europe were driven to the EU winegrowing policies. In particular, four periods can be individuated i) from 1960’s the policies aimed to develop/increase the productivity, ii) from 1980's the main aim was to reduce the grape supply through the reduction of vineyard cropped surface, iii) from the 1990's policies aimed to maintain the grapes supply that was reduced over the time, while iv) from 2000's there was an abrupt shift where the grapes supply was determined directly from the market and not from the policies with a particular attention to the sustainability of grape production.

According to the Organisation Internationale de la Vigne et du Vin (OIV, 2014) the sustainable viticulture can be defined as "global strategy on the scale of the grape production and processing system, incorporating at the same time the economic sustainability of structures and territories, producing quality products, considering requirements of precision in sustainable viticulture, risks to the environment, products safety and consumer health and valuing of heritage, historical, cultural, ecological and landscape aspects".

Why viticulture is so important even if it is not strategic for human feeding, accounting for 1% if compared to the cereals cultivated surfaces that are strategic for human feeding?

It is important because:

- i) produces wine that is an alcoholic beverage, with many faces, full of meanings and nutritional components, whose conscious consumption follow us from millennia, contributing to personal and social wellbeing;
- ii) produces table grapes, nutritious, refreshing, healthful (available from July to Christmas) from which energetic and fragrant juices are produced;
- iii) produces raisins that are nutritious and tasty ingredients, essential in many desserts and dishes.
- iv) It produces income as wines, table grapes and raisins are exported and appreciated worldwide even if produced only in temperate climate areas;
- v) produces landscape and rural development as winegrowing areas are highly required for tourism destination from Champagne region to Pantelleria island;
- vi) produces culture and cultural identity because from the Caucasus to the Iberian Peninsula, from Argentina to New Zealand, the wine approaches the cultures, tells the story and teaches geography.

So, one on the main aspect of viticulture sustainability is the link to the territory, indeed most of European viticulture produce territorial wine characterized by protected designation origin (PDO) and protected geographical indication (PGI) while low percentage of total wine production is devoted to commodity wine (categorized as general table wine). This is not only a characteristic of European viticulture as e.g. California has 300 winegrowing regions that produces territory wines. Territory for viticulture can be covered by plain, hilly and mountain areas of production. For the Italian case in the last decades an increasing reduction of vineyard cropped surface was observed according to the increasing elevation. E.g. in Veneto region (Italy) in 2010 the vineyards in mountain areas were the 29.0 % while in 2020 they still represents the 0.2% of total vineyards Veneto region (Figure 2). So, one of European challenge is to maintain the so called "eroic viticulture" in mountain and hilly areas as it is a fundamental component of anthropogenic landscape and historical heritage. On the contrary, concerning the viticulture in hilly areas, some Italian regions like Lombardy and Piedmont had maintained the vineyard cropped surface over the years and in some cases the cropped surfaces increased. The maintenance or increase of vineyard cropped surface in hilly area in the last 20 years was fully related to the land shaping practices that allowed the mechanization of vineyards and then the productivity and economic sustainability of viticulture in hilly area. Unfortunately, in that area land shaping in most cases leaded to soil destroying and landscape devastation. For land shaping, in some cases the soil is completely removed while in other cases the soil is mixed resulting in a chaotic structure. In both cases a considerable or total losses of fertility occurred resulting in a big variability of vineyard vigor, showing alternance within the same vineyard plot of zones characterized by huge grape yield and other characterized by very scarce grape yield. Another aspect to be considered for viticulture sustainability in hilly area is a prudent planning of new cropped surfaces to be placed in suitable areas according to geomorphological characteristics to avoid landslide and to protect the bare soil of new cropped area by tillage erosion.

Another important aspect of viticulture sustainability is the varieties heritage, selected over the centuries, that gives identity to the territories and produce the eno-diversity. To date in germplasm collections are listed more than 6,000 grape varieties over the world but few hundreds are grown for grape production with 13 varieties accounting for 37% and 33 varieties accounting for 50% of total world vineyard acreage. These data indicated that the biodiversity of world viticulture is very limited. Among European countries, Greece and Italy are the most biodiverse concerning the varieties assortment, with 29 and 25 varieties respectively. Considering the world countries with higher grapes production, lower than 10 varieties are grown in most cases further underlining a very low level of biodiversity varieties across the world. In general, the wines produced throughout world countries are very similar loosing the heritage of eno-diversity. Concurrently, also the wine makers that normally use local grapes varieties less widespread, recently tend to homologate their production to that obtained by other producers using the international varieties (Chardonnay, Cabernet and Sauvignon). Indeed, grapes of international varieties are mixed with grapes of local varieties in order to produce a wine for which the taste can be appreciated by international market. These practices lead to the impoverishment, simplification, trivialization, and sensory laziness of the world of wines.

Sustainability for sure also means the reduction in the use of pesticides. In this direction since 1990's a huge work in breeding varieties resistant to powdery mildew and downy mildew, main fungal diseases in vines growing, leads to the born of new varieties called "resistant hybrids". Crossing varieties characterized by 99% of genomes of *Vitis vinifera* and very limited fraction of genomes of other resistant American and Asiatic *Vitis spp.* it was possibly create new varieties able to resist to the main fungal diseases that can be considered at the same time likely *Vitis vinifera* from the enological point of view, with high potential for wine quality production. In this last 20 years more than 370 resistant varieties, with completely typical characteristics of *Vitis vinifera*, were obtained in 25 countries and registered for cultivation; in Italy 25 resistant varieties are in the national register. Although the resistant hybrids are not immune from fungal diseases generally, they require only two or three pesticide spray application per year vs. the 10-15 spray application per year generally required by not resistant varieties of *Vitis vinifera.*

Viticulture sustainability needs also to be referred to cultural values and identities where:

i) techniques are against traditionalism (e.g. biodynamics viticulture)
ii) scientific approach is against traditionalism (e.g. organic viticulture)
iii) cultural complexities are against localisms (e.g. marketing strategies to promote local small production at country or worldwide levels)
iv) social responsibilities are against environmentalism
v) local hierarchies are against stereotypes (e.g. importance of soil erosion vs. CO2 emission in viticulture production)
vi) concrete issues are against global biased influences

Best practices are also strategic for the sustainability of viticulture where the i) professionally trained, environmentally and safety conscious operator, ii) the conservation of vineyard environment (biodiversity and ecological function), iii) the site selection and preparation, iv) the site management (alleyways and weed-free strip), v) the rootstocks, cultivar and planting system for new vineyards, vi) the nutrition, vii) the irrigation, viii) the integrated plant protection and ix) the harvest management play a key roles.

Beyond the conventional and general parameters to be considered for the evaluation of viticulture sustainability, like water and carbon footprint, for a comprehensive sustainable viticulture there is the need to consider also the "vinicultural models" to be selected/followed for both economic and environmental sustainability of different growing zones. According to the growing zone, the different "vinicultural models" are based on the most suitable selection of:

i) vine varieties (traditional, international, alternative and for the future)
ii) type of wine (origin wine, varietal wine, commodity wine, alternative wine or author's wine)
iii) planting system, management system and the intensity of mechanization
iv) integrated production or organic viticulture
v) technological processes in wineries
vi) landscapes and shaping (relationships with urbanization, abandonment, hydro-geological risk management)
vii) rural housing and functional restoration, contemporary architecture, functional minimalism
viii) the socio-economic structure of the property, business forms, cooperation, forms and management
ix) interrelations with other economic activities in the area (tourism, cultural events, other food and agricultural products)
x) relations with the market (local, national, international markets, global village, hospitality and experiential marketing)
xi) eco-compatibility (use of resources, environmental protection, operator and consumer health, biodiversity)
xii) the professionalism of operators (workers, undergraduates, graduates, post-graduate)

As conclusion, the wine is a very complex beverage where using a metaphoric example the sustainability is the Atlas holding the world but also Noah drunk, drunk after he has saved the world.

3. Presentation 2 - Advanced technologies for precise viticulture (Emilio Gil & Fran García-Ruíz, Universitat Politécnica de Catalunya, Spain).

Three main topics related to the precision viticulture (PV) are considered in the presentation as they are the most interesting for the farmers because they expect benefits from the new and most innovative PV technologies. The three topics are i) pesticide spray application, ii) harvest and iii) pruning.

The PV is driven by the variability of canopy vigour or yield within the same vineyard parcel. The vineyard parcels with greatest opportunities for PV are those which reveal a high degree of vigour or yield variation. A high degree of variation will mean higher variable rate application (VRA) of inputs and, therefore, greater economic and environmental benefit in comparison with uniform management. Not only the variability in the parcel can be considered for PV but also the canopy morphology variability due to the different vine varieties and especially the variation of canopy morphology along the growing season that require different management according to the growth stage, canopy density and shape.

So, the first step in PV is the data acquisition of canopies parameters/characteristics that can be used later on for VRA inputs like fertilizer, pesticide applications or harvest. In this sense, recently a ground drone called “vinescout” able to navigate autonomously the vineyard parcels was developed and used for vineyard scouting; this robot analyzes thousands of data points from canopy temperature to nitrogen levels, all obtained via a 3D stereoscopic machine vision system, lidar and ultrasound sensors (http://vinescout.eu/web/).

In PV the spray application is one of the most important issues because give the possibility to practically i) reduce environmental and human contamination risk ii) improve PPP benefit and iii) raise food quality and safety standards by reducing chemical inputs. Indeed, conventional application in vineyard foresees two time more the use of pesticide than those used for arable crops like wheat or corn. In this light, a precise and georeferenced canopy characterization allows the implementation of VRA spray techniques in vineyard, whereby pesticides application rates are modified according to crop characteristics with demonstrated benefits in terms of pesticide dose reduction, drift control and uniform deposition. The PV spray application techniques acquire even much more a strategic role considering the European Green Deal that in the ambit of Farm to Fork Strategy strives to reduce the use of pesticide by 50% within the 2030. As practical example, in the ambit of research activities carried out by the UMA team (Agricultural Machinery Unit belonging to Polytechnic University of Catalunya), a series of different sensors was used from a long time for scouting the vineyard canopies in order to obtain a georeferenced canopy density data and then used to generate prescription maps. The most used and promising sensors are ultrasonic sensors, LIDAR technology and multispectral camera. So based on the information acquired using sensors a prescription maps describing the density of vineyard canopy within the parcel was obtained and simplified for practical application defining three levels of canopy density, corresponding each level to a spray volume rate to be applied. In this sense UMA researchers starting from the normalized difference vegetation index (NDVI), measured using multispectral camera installed on unmanned aerial vehicle (UAV), obtain a vineyard vigor map. Then, the relationships between NDVI and tree row volume (TRV) was investigated in order to finally define the most adequate volume to be applied according TRV used as inputs for pesticide VRA (Figure 3). Ad hoc technology is required for pesticide VRA, and to date sprayer equipped with central unit able to read the prescription maps and navigate it thanks to the use of GPS are available in the market. According to the position of the sprayer in the field different inputs about the canopy density was received by the central unit of the sprayer and then it can automatically vary the spray application rates varying the spray pressure and/or selecting automatically different nozzle size and type thanks to electro valves able to switch from one nozzle to another one. As example WAATIC (https://www.waatic.com/en/) is an innovative standalone smart control system for spray application already available in the market able to read prescription maps and give inputs to the sprayer to obtain pesticide VRA. The system can be installed on new sprayers or integrated on in-use sprayers once equipped with suitable sensors and hardware needed for VRA purposes.

However, the use of prescription maps that describe vine canopies characteristics is not so diffuse among farmers and to date it is something more related to research purposes as the procedure to create the prescription map is not automatized and require very high-level expertise. So, a decision tool for a better dose expression during pesticide application in vineyard was developed and it is now free available. This tool is a smartphone app named DOSAVINA® (https://dosavina.upc.edu/) and it was developed with the aim of helping farmers in the important process of determining optimal volume rates for spray applications in vineyards according to the main canopy characteristics. In few steps, based on few and very basic canopy measurements/evaluations, farmers are able to define the optimal volume rate to be applied in their vineyard parcel at the time of application. The final developed tool resulted good example of bringing research to potential daily application by end users. The app is based on a modified method of LEAF WALL AREA (LWA) and includes spray calibration support. This last consideration regarding the calibration process is properly highlighted in the app, as one of the conditions for a good success of the entire process.

Considering the high cost of equipment needed for vineyard scouting using UAV and the high level of expertise needed, by operator to drive the UAV in the field and after by expertise to process data, recently was investigated the possibility to obtain useful information about vineyard canopy characteristics using satellite images. The pro of satellites images is that they are freely available, and constant updated as at least satellites make one rotation per day around the world. Recent results obtained by UMA team underline that the precision of canopy characterization obtained from satellite images is lower than those obtained from images of multispectral camera installed on UAV making ad hoc vineyard parcel scouting. Anyway, useful information about vineyard canopy characteristics can be obtained by satellite images and used for VRA purposes in an effective-cost way.

Recent experience conducted in vineyard in the ambit of OPTIMA H2020 EU project (http://optima-h2020.eu/) investigate the possibility to perform pesticide VRA according to canopy disease incidence within the vineyard plot. An Early Detection System aimed to individuate the powdery mildew disease symptoms on vine leaves before those are visible to the human eyes was developed. One scan per week of entire vineyard plot were performed along the whole growing season and from each scan a prescription maps indicating the presence and severity of the crop disease within the plot were created for pesticide VRA accordingly. Concurrently, within the project, a trailed tower-shaped vineyard smart sprayer was developed and tested under field conditions throughout the growing season (https://www.youtube.com/watch?v=9Klx2EYuqgU). Thanks to a GPS the smart sprayer was able to read the prescription maps uploaded before starting the spray application. For VRA application the nozzle flow rate, therefore the PPP dose applied, was automatically tuned along the rows using Pulse Width Modulation (PWM) nozzles technology. PWM solenoid valves coupled with nozzle holders allowed to vary the duty cycle of the pulse signals from 30 to 100% to change the spray outputs accordingly (at a frequency of 20 Hz). This technology allows to vary the nozzle flow rate in a wide range without varying the spray pressure and then without modifying the droplet size spectra generated with documented benefits in both spray drift reduction and canopy deposition. Furthermore, an integrated system enabling to vary the fan revolution speed continuously according to the canopy presence and density was developed and mounted on a prototype vineyard airblast sprayer. The system consists of two ad hoc designed ultrasonic sensors, able to determine the canopy density, whose output commands an electrically driven axial-fan through a controller. The density values are received by the controller and then processed through an algorithm. The set fan revolution speed is then communicated by the controller to the electrically driven fan inverter. The parameters of the sprayer fan air stream, namely airflow rate and velocity, are crucial factors influencing the quality of the spray application and the amount of off-target spray losses when using an airblast sprayer in 3D crops. Indeed, field trials demonstrates that the sprayer prototype providing VRA of fan airflow can substantially increase canopy deposition and concurrently decrease spray drift compared to the commercial version of similar sprayer equipped with a conventional mechanical axial fan.

Other strategic tool in the ambit of PV is represented by Decision Support Systems that are informatic tools connected to a weather station network or directly to a weather station placed in the field and thanks to the integration of weather data and predictive algorithms specific for a specific disease help farmers to schedule the spraying based on disease risk. A lot of DSS are now available for the farmers and field technicians; among those available is worth to mention the DSS developed in the ambit of OPTIMA H2020 EU project (http://dss.optima-h2020.eu/) that is free of charge and vite.net from Hort@ (https://www.horta-srl.it/vite-net/). The use of DSS can reduce spray application frequency and overall pesticide usage. Recent results underline that for a given fixed number of fungicide sprays, decision support systems were as effective as calendar-based programs in reducing disease incidence.

Concerning the grape harvest the potential benefit of PV technique are mainly related to the selective grape harvest to produce high quality wine. In these senses, based on NDVI vine canopies maps the quality of grapes within the vineyard plot is divided in classes through cluster analysis, from the higher to the lower quality. Based on the grape quality map obtained the plot map is further simplified and the zoning of vineyard plot was made according to the grape qualities. Smart grape harvester able to read the prescription maps containing the quality grape zoning was able to harvest and store the grapes in different box according to the quality. So, from the same vineyard plot can be produced wine with different characteristics and quality increasing the economic benefits for farmers.

The future of PV will involve robotics. To date there are many research centers working in how robots can assist in yield prediction, weeding or even pruning in viticulture, but it is especially in France, where this research is coming into the market with some commercial solution mainly aimed to weeding and arrowing operations (https://www.naio-technologies.com/en/ted/ and https://vitibot.fr/?lang=en). More recently robotic research is focusing on detecting clusters, counting them and allowing a precise and early forecasting of yield. Small autonomous platforms fitted with different optical sensors and actuators are being used to determine phenological characteristics, detect clusters via image analysis algorithms and even in some cases act accordingly by harvesting the ripen grapes. The new frontier is the cooperation between human and robots. In this case the robots are called "cobots". This novel approach for autonomous robots' employment was already introduced in indoor controlled conditions (industrial settings), also because of the challenges raised by outdoor environments. The CANOPIES project (https://www.canopies-project.eu) aims to develop a novel collaborative human-robot paradigm in the industry of table grape to address two major tasks carried out in the field namely harvest and pruning (Figure 4).

Concerning pruning it is one of the most challenging tasks to be addressed in the future using robots as it is a very thorny field operation that require a lot of time and specialized operators because from the pruning depends on the yield of vineyards and also the quality of grapes. To date there are a lot of research project aimed to develop PV technologies aimed to autonomously carry out the pruning in the vineyard, but not commercial solutions are now available.

Apart from improving new solutions and developing cutting edge technology, there exists a big gap from science to industry that needs to be filled with more training and formative programs as well as easy access to the developed prototypes and methodologies. INNOSETA is an EU project (http://www.innoseta.eu/) that helps to bridge the gap between the farmer and latest technological and knowledge developments in the agricultural sector, in which viticulture is included. The platform is divided into four areas: projects, training material, industry solutions and articles. Each user can upload information relevant to the sector, which goes through a selection process and is published in eight EU languages. Operator training and improving the farmer's skills and experience about in using PV techniques and technologies remain the most effective way for a more efficient viticulture. In this sense the European Union has founded some projects in the last 15 years and recently founded a project called AgrICT: training for Precision Agriculture (http://www.agict.upc.edu/) which main aim was to increase the adoption of new technologies among professional farmers as it is in the foreseeable future the main way to achieve a more efficient, efficacious, and sustainable viticulture complying the even more stringent UE regulatory requirement.

4. Presentation 3 - Grapes mechanical harvesting (Thierry Le Briquer, CNH Industrial, Italy).

The specialty permanent crops, namely crops that life cycle is from 15 to 100 years (e.g. orange, olive, orchards, vineyards, etc.), in the period 2000-2016 increased in terms of cropped surface (+5.5%), yield (+20.5%) and production (+24.0%), and these performances are strictly linked to the mechanization increase. The specialty permanent crops are facing some difficulties due to the water restriction needed to conserve water resources and limit runoff and concurrently the average environmental temperature is continuously rising all over the world. As example the olive crops in south Spain in 2021 for the first time suffer the drought and hot temperature. Furthermore, as to date consumers well know the high inputs of chemicals generally used for the fruit production, they are even more searching for products that guarantee, through certified link between final product and field practices, fewer chemical inputs during the whole growing cycle (sustainable agriculture) in order to have both safer and healthy commodities (organic food) and environmental protection benefits. The environmental changes drive the customer trends and requests, so New Holland (brand of CNH industrial) with innovative technologies try to support this global trend.

The overall cropped surfaced covered by specialty fruits is about 55 M ha of which olive, coffee, grapes, apple, banana, orange, and almonds together with pistachio account for 10, 10, 7, 5, 5, 4, 2 M ha, respectively. These seven main crops with 43 M ha represent the 78% of total surface cultivated by specialty fruits. This surface is relatively small if compared to the wheat cropped surface, accounting for 220 M ha, but it is highly profitable. Considering just the income of the fresh fruit harvested the specialty fruit crops are five time higher profitable than the wheat. If the transformation is considered the incomes are much higher. On the other side the mechanization level in specialty fruit crops is very low as there are still a lot of manual operation that can be replaced by new technologies able to increase productivity and crop profitability. As example, one of this operation is the grape harvest. 45 years ago, competitor cash crops accept the introduction of CNH grape harvester and today the grape harvester represent 55% of share. Similarly, the Ne

Holland specialty tractor were introduced over the years for the production od specialty fruits and they represent 24% of share. In this niche business New Holland is one of the most important brand in the world and it is doing huge investments to address the customer needs and the challenges of future vineyard mechanization that we have in front of us.

Considering the yearly vineyard work cycle, 365 days of new challenges are facing. The year work cycle in vineyard can be divided in four main activities namely i) canopy management, ii) soil management, iii) crop protection and iv) harvesting.

Concerning the canopy management, the pruning operation is the major issue as it is a repetitive activity made manually by specialized operators during winter season and it's very difficult to find enough willing operators during the pruning period. Furthermore, the type of pruning has to be selected by qualified technician and the grape yield and quality of next year depends on it. Nowadays there is a trend to mechanize pruning operation, but it is well known that the actual machinery for pruning are aggressive and not precise enough to guarantee uniform and optimum fruit quality. So, one of the challenges for the pruning machinery of the future is to understand/define where to prune the branches accordingly their physiology. Second important issue is the proper soil management especially in permanent crops as they are monoculture super intensive crops that remain in the same place for a very long time and this situation is against the well-known logic of rotating crops. Furthermore, in vineyard in these last years a chemical weed control was largely and successfully used performing from two to three spray application per year. Nowadays the viticulture is coming back to the past returning to mechanical weed control using light tillage techniques. The mechanical weed control technique/machinery have to be able to balance the soil tillage and weed control efficacy guaranteeing a certain level of ecology in the superficial soil layer (10-20 cm) and avoid at the same time the soil compaction in the alleys due to the tractor passages. The mechanical weeding is against the ecology as it requires a higher use of tractor, to guarantee a similar level of weed control than those obtained with chemicals, with negative impact on carbon footprint. Another aspect well documented is the possibility to physically damage or terminates vines, that in this last case must be replaced, with consistent losses of grape yield throughout the future years as young vines took 10 years to achieve a full production. The third issue is the vineyard crop protection for which the main concern is related to the spray drift phenomenon that in case of windy conditions can be generated during the spray application facing risks for non-target receptors like environment (e.g water courses, etc.), non-target crops and/or bystanders. So, the main objective of innovative spray application technologies is to maximize the canopy deposition while minimizing the off-target losses especially those related to spray drift. Furthermore, in the ambit of precision viticulture, to reduce the chemical pesticide inputs, the innovative technologies have to adapt the spray application rate (VRA) according to the needs and then to the canopy morphology ensuring to spray just the minimum amount needed to ensure biological efficacy of pesticide applied and only where needed. The fourth issues, in which New Holland is involved from the last 45 years, is the grape harvesting. Throughout the years the New Holland grape harvester technologies/machineries had a lot of improvement and to date the quality of grape harvested mechanically is very similar or better to those harvested manually on large scale by army of workers. The manual harvest shows a better quality only on small scale where the operator pick cluster by cluster with care; this is the case for the very high-quality grapes used to produce premium wine. Furthermore, nowadays there are a lot of high technologies that few times ago there were not available like robotic, electrification, cloud and data analytics, artificial intelligence, etc. One on the new challenge for CNH is to find competent partners to develop and implements this new technology for final market solution grape picking.

Basically, the mechanical grape picking can be divided in five steps that are continuously repeated along the vineyard rows (Figure 5). The first one is the removal of the fruits/clusters from the trees through a shaking system that creating a lateral acceleration to the ground detach the clusters that are collected inside a basket. In the second step the collected clusters were transported from the bottom to the top of grape harvester machine thanks to ad hoc shaped conveyor belt. Once the clusters reach the top part of harvester machine start the cleaning of fruits consisting in three steps. The first cleaning step consists in remove the big leaves and pieces of vegetative material with big surface. Thanks to a fan the leaves are sucked and blown away on the back part of the machine; this fraction represents the 5% of material other than grapes (MOG). The second step of cleaning is the destemming where a mechanical system, installed in the top part of harvester machine and composed by rubber fingers, gently separates clusters from stalks to obtain the grapes and the scrap fraction represents the 0.3-1.0% of MOG. The third step is called sorting and at this stage the small pieces of vegetative materials like leaves that remained on the clusters are further separated and this fraction represent the 0.1% of MOG.

As mentioned before, to date the mechanical harvester are able to guarantee harvested grapes quality similar to those harvested manually, so the new development/improvement of mechanical grape picking is focused on the productivity. It means harvest faster and at the right moment of grape ripening because grapes are characterized by peak of 48 hours corresponding to the optimum timing for harvesting. So, one of the challenges of grape picking is to be on time, respecting the ripening peak optimum. At the same time New Holland is continuing to invest in operator safety especially in viticulture where the tractor and/or harvester tilting can exceed the overturn angle in slopy hilly area facing high risks for drivers. The approach is to further develop the rollover protection structures (ROPS) and continue doing proactive activity safety as well. The other important safety aspect is related to the cab. All New Holland tractors and harvester has installed cabs of category four (protection from dust, gas and aerosol) with a double system of filtration able to work accordingly the agricultural operation the farmer is doing. As example when the farmer is doing soil tillage that requires protection just from dust the air filtration system use a filter of category 2 while the farmer is performing pesticide spray application the system work through filter of category 4 because protection from pesticide aerosol is required. In this way for each field operation the driver is protected at the maximum level. Also, the driver comfort is important, and New Holland is continuously improving it. What is important is to make the controls in the cab easy to use for the operator and to increase the access to the components that need daily maintenance like washing. Indeed, the tractors need to be washed every day at the end of the work to avoid operator contamination. The tractor and its components washing is a stressful activity at the end of daily work after 8 to 12 hours driving; an easy access to all components making comfortable the washing activity strongly reduce the time required for it. Another important task in the improvement in the sustainability of engines through hybrid technology and the improvement or substitution of hydraulic circuits in order to minimize or avoid oil losses in the environment and on the grapes in case of harvester machine.

As mentioned before the vineyards are permanent plantation and farmers pass about 20 times per year in the same rows meaning that at different time along the year, farmers using tractors or grape harvesters, could scan the wine stock about 20 times. So, farmers can have an exact figure of evolution of wine stock along the year. This means that approximately a picture of 20 billion wine stock per year can be obtained worldwide to know the worldwide viticulture situation. The New Holland idea is to collect at worldwide level those information/figures and together with the service/data providers analyze those data to capitalize the history of wine stock in order to achieve a better production and diseases management. As example, knowing the evolution and behavior of diseases in the last 50-60 years for some regions could help other regions to plan preventive strategies to control that diseases in the following years. One of the core technologies of New Holland launched in 2009 is the Oenocontrol machine gold medal awarded in SITEVI exposition. It was a concept machine able to select different grape quality within the same block according to the NDVI or other parameters like vine stress providing a direct relationship between vineyard physiology and food quality. The oenomachine was provided of two hoppers placed on the right and left sides and thanks to the possibility to upload and read a prescription map, describing the quality of grapes, the harvester was able to automatically recognize the grape quality based on the positioning within the field and the grapes were collected in the hoppers A or B according to the standard or premium quality.

The key direction for the following next years will be the mapping of vineyard with acquiring parameters useful for the whole growing cycle in order to address a better and more sustainable viticulture. In the next future the digitalization of the full vineyard cycle will allow to record field data used for traceability tasks and to built maps to be used for spreading, spraying, harvesting, etc. As example prescription maps used for fertilization purposes can allow to increase the grapes yield and reduce the chemical inputs at the same time applying only the right amount needed and where needed.

Even if the field traceability along the growing season is very important the final aim is the full traceability of the wine bottles from the vineyard to the final consumers (Figure 6). As example the full traceability for wine bottle means to link each bottle to a vineyard parcel and know how many, when and type of pesticide applications was made along the growing season, linking the grapes harvested to the cellar, knowing which method is used to extract juice and in which barrel was placed and for how many times was ageing; briefly the aim is to know the whole history of each wine bottle. In this sense New Holland, within an internal project called Agriculture 4.0, is preparing a cloud in which each service provider involved in the chain production of wine along the process collect data and share these data in the cloud. The data uploaded in the cloud step by step along the production process from the field to the wine bottle fed the pipeline and finally crossing the data the full traceability/history of each bottle is available and can be consulted by end-consumers through QR code technology placed on the bottle label.

New Holland has long history of innovation and recently it was awarded with gold medal at SITEVI 2019 exposition for its dual software solutions, Plug-and-Play and Multipurpose-on-Demand, both of which are designed to enable the customer to use a range of implements on straddle tractors and Tier 4 New Holland grape harvesters without the need for external assistance, thereby enhancing both productivity and operator comfort. The Plug-and-Play software can be used on all tools designed in collaboration with selected partners such as BERTHOUD Curis'Air sprayers and the PROVITIS Omega range. It works by enabling the grape harvester tractor unit to automatically recognize the implement selected by the customer, adjusting the settings and screens on the in-cab monitor accordingly. For all other brands of implements, New Holland has created the Multipurpose-on-Demand software solution. The customer's dealer will create a bespoke software program for each implement, assigning functions to buttons on the machine's multifunction handle. Once this initial set up has been completed, the machine will recognize when the customer connects the implement, automatically adjusting the settings on the in-cab monitor and multifunction handle. The two solutions also enable the customer to take full advantage of New Holland's Intelligent Management System 2.0 (IMS 2.0), winner of the SITEVI Bronze Medal in 2017, reducing their cost of ownership and maximizing their profitability. The IMS 2.0 constantly adjusts to the lowest engine rpm, saving fuel on the road and in all working modes.

5. General Remark and Key Sentences from the Session Participants

Viticulture is fundamental sector at international level. It will be very important to reconsider the concept of sustainability applied to the viticulture. Sustainability in viticulture will be more and more strategic in the future and mechanization can and must help producers to achieve a sustainable viticulture. Sustainability in viticulture has to take into account for sure the i) environmental aspects, producing safer product for the consumers with lower chemical inputs and carbon footprint, but also ii) cultural aspects, protecting the varieties heritage selected over the centuries that gives identity to the territories, creating anthropogenic wonderful landscape and produce the eno-diversity.

Various advanced precision agriculture technologies such as vineyard mapping for variable rate application/picking purposes and robotics able to improve sustainability, reducing environmental pollution, are to date available. However, the adoption of these technologies is still low by farmers. In general, can be individuated two levels of vineyard farm: the big one that is asking for and are ready for advanced mechanics and robotic autonomous techniques mainly for pruning, spray application and harvesting operations and the small farm, "family owner" characterized by vineyard surfaces between 5 and 10 ha, where the adoption of high-level technologies is still far but they are ready for the "basic" advanced techniques. In both cases training is fundamental as it is the unique strategy for the adoption and the right use of new advanced technology in the every-day farm activities. If farmers are not adequately trained for the technologies adopted the innovative solutions will remain a concept machines for research purposes. Even if the vineyard mapping using a UAV it is well recognized to be effective in spreading fertilizer, protect crop and picking grapes reducing chemical inputs in a timely manner and increasing the productivity and related incomes, a further essential step for the adoption of this new innovative solution is needed. In this way the automatization of crop/vineyard monitoring in order to make freely available and accessible to all farmers detailed data about the situation of its vineyard along the season is strategic, otherwise farmers are not willing to extra pay an external service for monitoring purposes. As final remarks the innovative mechanization machinery/solutions have to be adapted/improved for their accessibility to the sloppy area (e.g. tunnel row sprayers, grapes harvester, etc.) as they can highly help vineyard farmers in hilly and mountain areas where the use of machine to date is very limited. This will reduce the costs of production making mountain and hilly viticulture more profitable as consequence reducing the abandonment of mountain and hilly viticulture that from century represent the heritage of eno-diversity. Furthermore, the zoning of vineyard according to the grape quality to produce different wine qualities associated to the use of grape harvester able to autonomously differentiate among grapes quality it will be a huge opportunity for farmers to cut the operating costs and increase the revenue of the farmers thanks to the production of differentiated grapes quality (higher grapes quality means higher quantity of premium wine). It will be of fundamental importance in this process the capability to fully trace this high-standard production in order to tell the history of wine from the field to the consumer's table. In this sense cloud services with blockchain technology could be suitable tool.

An important help to increase the viticulture sustainability, to be used as support of precision viticulture tool, arrives from the new hybrid varieties that are resistant to a large array of diseases and can strategically reduce the chemical inputs due to the crop protection activities without loosing wine quality as it is demonstrated to have high potential for the production high-quality wine. On the contrary, the increasing requests for organic wine/grape productions from the consumers play against the sustainability as larger number of treatments per year is required (+30% at least) if compared with conventional IPM crop protection strategy, higher soil compaction due to the higher number of passes in the vineyard alleys with tractors and related higher impact on carbon footprint due to higher tractor use. Anyway, further investigation aimed to objectively compare the sustainability of organic production with the conventional production using precision viticulture techniques are needed.

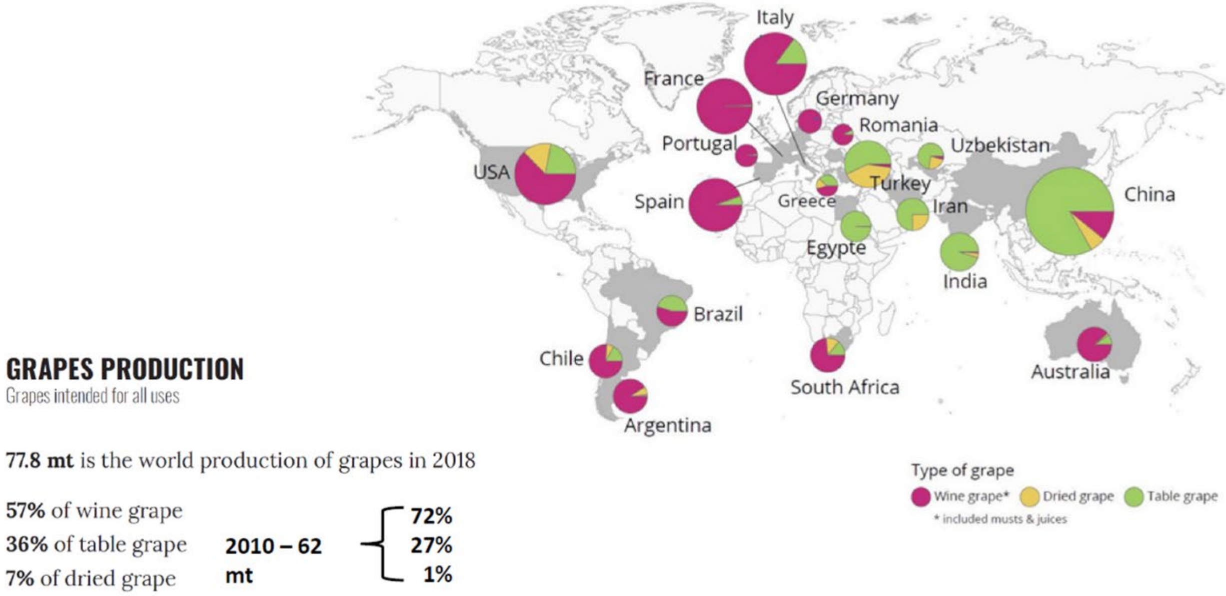

Figure 1: Current situation of world grapes production.

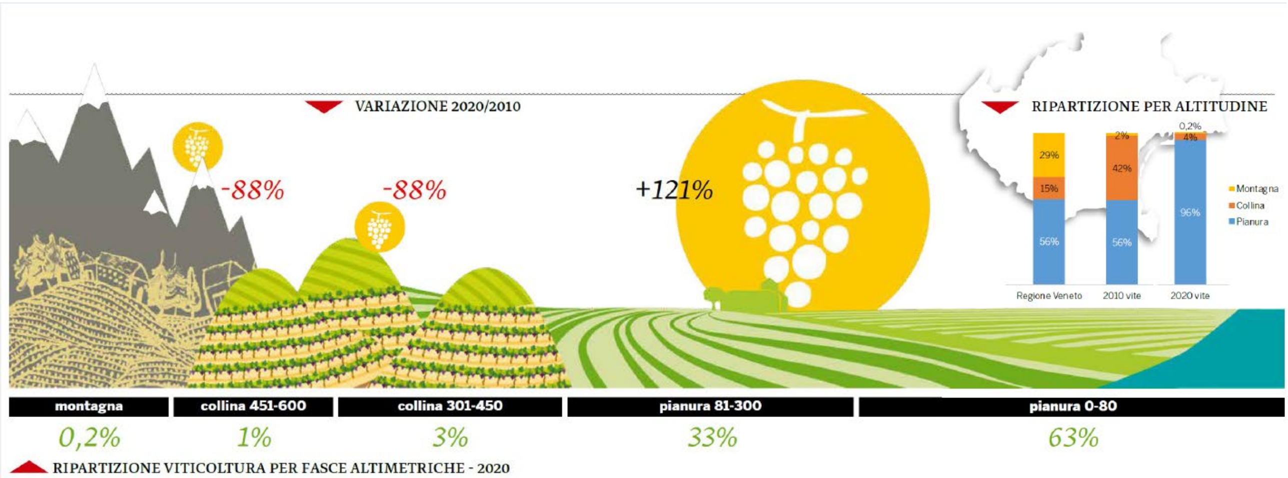

Figure 2: Distribution of viticulture according to the altitude and its variation in the last decades: the example of Veneto region in Italy.

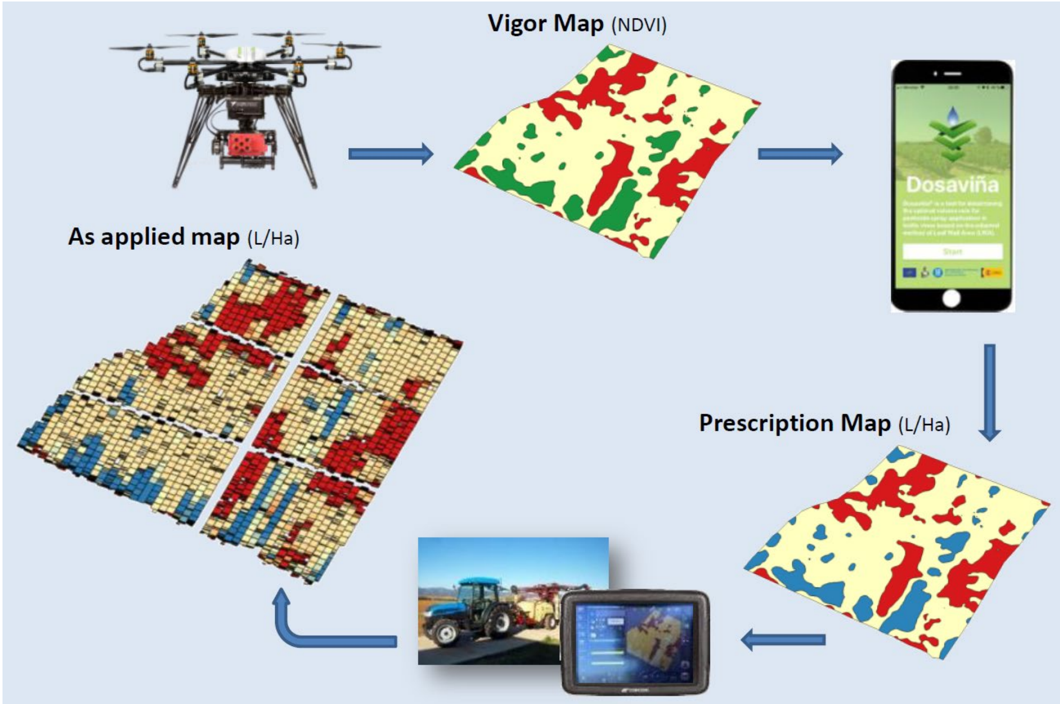

Figure 3: Conceptual procedure for the creation of vigour maps, based on multispectral camera measurement installed on UAV, for variable rate spray application in vineyards.

Figure 4: Schematic about the new frontiers in cooperation between human and robots developing a novel collaborative human-robot paradigm in the industry of grape production (https://www.canopies-project.eu).

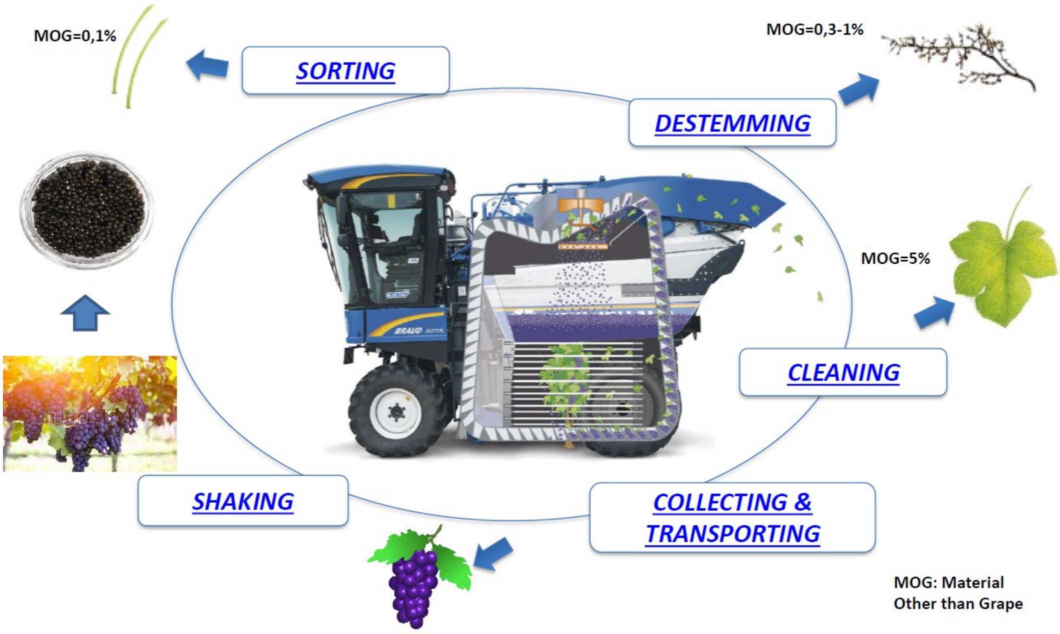

Figure 5: The basics of grapes picking.

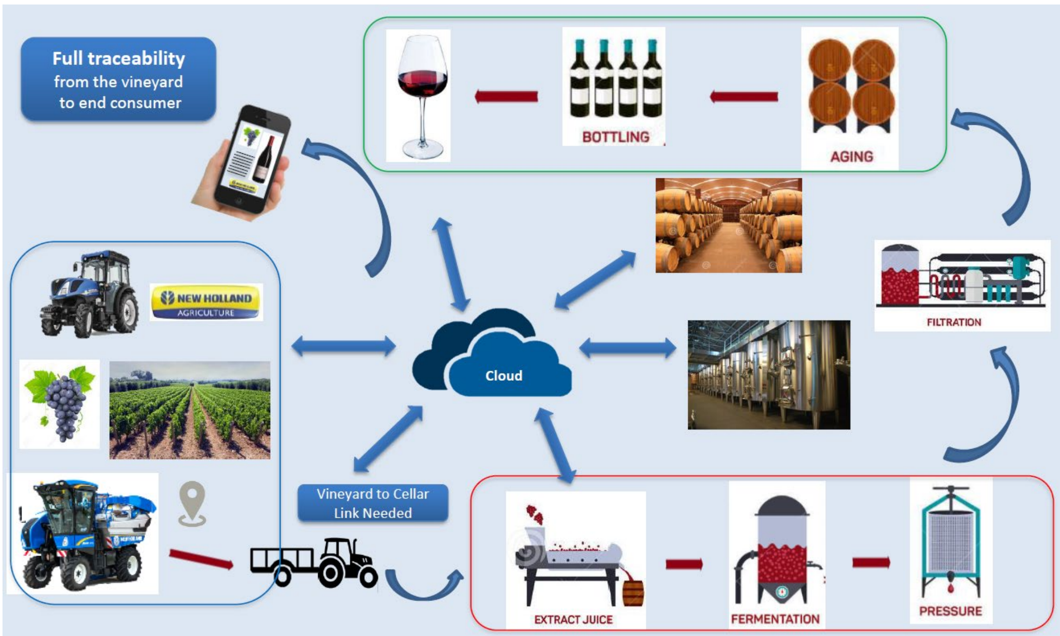

Figure 6: New Holland viticulture 4.0: the full traceability of wine production from the field to the consumer tables for the valorization of different wines and their quality.