Drought Resilience Improvement in Vineyard Ecosystems

LIFE19 ENV/IT/000035

Report on SWOT analyses of data from stakeholders’group

Action B2

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Summary

A SWOT analysis was performed to evaluate strengths, weaknesses, opportunities and threats of the monitoring tool (MT - PocketDRIVE App) and the resilient techniques, based on the stakeholders' (SHs) feedback.

SWOT Analysis

SWOT analyses derive their name from the assessment of the **Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T)** faced by an industry, sector, company or any organisation (Gao and Peng, 2011). The idea of a SWOT analysis has its roots in strategic management research conducted in the 1960s and 1970s (Sevkli et al., 2012), and arises from the perspective that the performance of a given (typically, but not only, economic) agent with respect to a particular objective depends upon the way in which the management of that agent interacts with both the internal characteristics of the agent, and the broader external context in which the agent must act (but over which the agent has no direct control in the short term) (Houben et al., 1999).
The value of a SWOT analysis stems not only from its ability to highlight ways in which an agent's internal and external environments interact to affect its success (Houben et al., 1999), but also from its ability to be used in the development and implementation of long-term strategies to achieve particular objectives (Houben et al., 1999; Gao and Peng, 2011; Sevkli et al., 2012). There are various classes of strategies that can follow from a SWOT analysis: e.g. those that link Strengths and Opportunities ('SO Strategies'), those that link Weaknesses and Opportunities ('WO Strategies'), those that jointly focus on the Strengths and Threats ('ST strategies'), and those that arise from the joint assessment of Weaknesses and Threats ('WT Strategies'). For example, SO strategies utilise the fact that Strengths may help to capitalise upon external Opportunities, whereas WO strategies focus upon the pursuit of external Opportunities to lessen the severity of Weaknesses. Similarly, ST strategies focus on the potential for existing internal Strengths to mitigate the impact of external Threats, while WT strategies consist of actions intended to reduce both internal Weaknesses and external Threats simultaneously (Sevkli et al., 2012).

The monitoring tool

The Monitoring tool (MT) has been developed to help farmers to better evaluate and manage the soil water storage in vineyards and promptly detect early water stress conditions. The core of the MT is the smartphone application PocketDRIVE, which implements approaches and algorithms to easily estimate — by using the sensors available in any smartphone (e.g., accelerometer, magnetometer) — key biophysical variables for effectively managing water scarcity issues in vineyards, such as

- the leaf area index of the canopy and of the inter-row grasses, if any (Confalonieri et al., 2013; Orlando et al., 2016), and
- the stomatal conductance of vines. The latter is derived as a function of
    - synthetic indices of 3D canopy architecture, derived by implementing the algorithms of the app PocketPlant3D (Confalonieri e tal., 2017), and
    - the relationships between such indices and the stomatal conductance derived during the experimental activities carried out in the DRIVE-LIFE Project (Paleari et al., *submitted*).

As a result, PocketDRIVE allows to promptly detect water stress occurrence and severity (i.e., mild or severe water stress) in a few minutes, by simply 3D scanning around ten leaves in the middle of the canopy with any common smartphone. The experimental activities conducted so far highlighted a clear cultivar-related effect on the relationships between canopy architecture and stomatal conductance, which are currently available for seven widely grown cultivars (i.e., Malvasia di Candia Aromatica, Croatina, Pinot Noir, Pinot Blanc, Sangiovese, Montepulciano, Chardonnay). More details on PocketDRIVE functions and scientific basis can be found in dedicated deliverables (***Action B1***).

The water resilience techniques

Soil management techniques

Between row temporary grassing

The soil management techniques implemented in vineyards involved the use of autumn-spring grassing to increase vineyard water resilience (Fig.1). Winter cover crops, an alternative to permanent grassing and total tillage, were then terminated at spring according to the following modalities:

- green manuring (GM),
- inter-row mulching obtained by rolling (R)
- piling of grass under the row resulting from the interrow mowing (“mow and blow”) (SR)

Seed mixture for grassing

The composition of the sown seed-mixtures may involve the use of different proportions of cereals, legumes, brassica and other botanical families according to the specific needs of the vineyard. The field trials selected a seed-mixture with predominance of cereals (C), one with mostly leguminous (N) and a third one (B) with a more balanced legume-to-cereal ratio completed by a small fraction of brassica and other species. (Fig. 2)

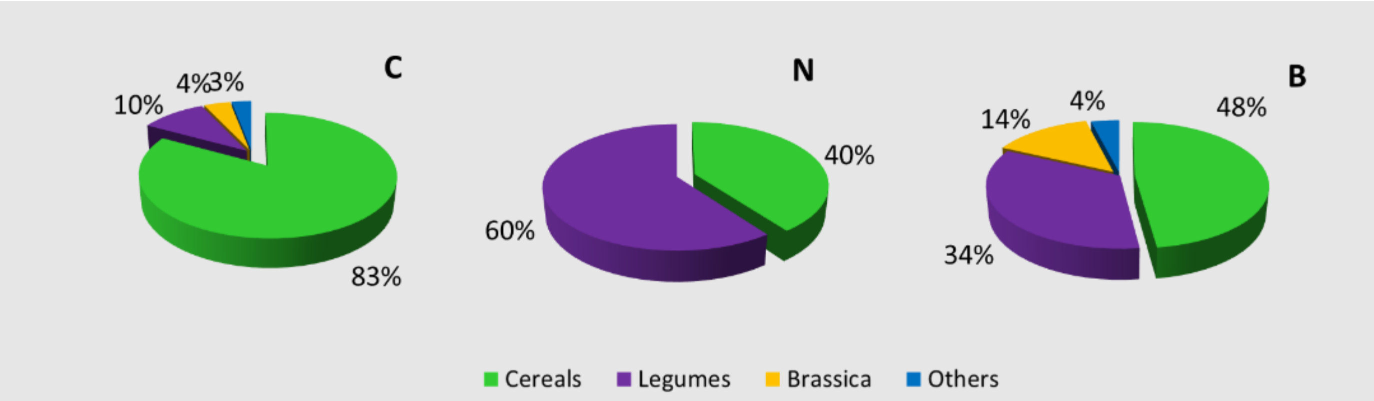

Figure 1: cover crops seed mixtures composition used in DRIVE LIFE project

Techniques applied for biomass termination

Winter cover crops were terminated in spring according to the three following techniques.

Green manuring (GM): it implies mowing and subsequent burying in the soil of the biomass grown over winter; the aim is promoting the release of nutrients and enhancing its water holding capacity. According to agronomical needs, a seed mixture with a different ratio of cereals, legumes and brassicas is used.

Between-row mulching (R): it requires a crimper roller to press biomass produced between the rows, creating a permanent mulching layer. This technique is considered beneficial for saving soil water content due to the formation of a 'coating' that reduces direct evaporation and transpiration of the plot, as well as the growth of potential weeds in proportion to the amount of produced biomass.

Piling of grass under the row ("mow and blow") (SR): it is achieved with a special mulcher that conveys the residues under the vines, forming a localised mulch strip. In addition to maintaining moisture in the soil, weed growth is naturally controlled with minimal recourse to tillage over the remainder of the season.

Sowing and transplanting of ground cover species under the rows

In addition to the specific trials concerning temporary grassing management, a trial of planting/sowing ground cover species under the trellis was run (Fig.5). Herbaceous species from different botanical families all having attitudes to suffocating growth patterns were established with primary aims of limiting the growth of native weeds while preserving soil structure and alleviating erosion issues.
Several pre-tests were made by UCSC to identify species with lower water consumption and best suffocating properties. The selected ones were: *Dichondra repens, Trifolium subterraneum, Glechoma hederacea, Pilosella officinalis, Festuca ovina, Festuca rubra* rubra.

Canopy management techniques

Resilient canopy management strategies implemented during the project to preserve plant water status and limit overheating damage involved the foliar applications of kaolin and anti-transpirants. Kaolin rock powder is able to reflect solar radiation resulting in a cooling effect of canopies and clusters. The anti-transpirant used in DEMO vineyards reduces canopy transpiration through the formation of a film that partially occludes the stomata and, in turn, slows down the leaf gas exchanges.

Demo farms action plans

In Table 1 the techniques chosen for each demo farm are summarized.

Demonstrative vineyards were selected according to the following considerations:
- uniformity of vineyard and soil management.
- uniformity of vine variety to enable the analysis of vine behavior through the data collected during harvest and pruning time.
 localization in one of the two wine districts being the focus of the DRIVE LIFE project: Colli Piacentini (VCB, GNP and CRT), and Oltrepò Pavese (BPR, SMV and CNV).

Table 1: selected resilience techniques for each DEMO farms with indication of the cover crop seeds mixture choose

TECHNIQUE	SOIL MANAGEMENT										CANOPY MANAGEMENT
SEED MIXTURE	N			B			C			SUB-ROW GRASSING	
TERMINATION T.	GM	R	SR	GM	R	SR	GM	R	SR		
VCB[1]	X			X			X				
GNP	X			X							
CRT								X	X		
BRP	X			X							
SMV	X	X	X				X	X	X	X	
CNV								X			
VCB_2											X

Tools for SWOT assesment

[1] DEMO farms codes are refereed to Deliverable B2.1 "Report on chemical-physical features and hydraulic properties of selected vineyard soils"

DRIVE LIFE project was developed on a participatory approach aimed to involved SHs in the definition of best practices for vineyard management and in the development of the Monitoring Tool for the detection of early water stress in vineyard.
This approach guarantees the future replicability and transferability of project outcomes on the whole value chain.
Several tools were used to collect feedback from involved SHs:

Table 2: Tools aimed to collect feedback from Involved SHs

Tool		**Target**		**Comments**
Questionnaire		Farmers Technicians Agronomist		see also Deliverable *"Report on activities to increase stakeholders' awareness"*
	Monitoring Tool		IT and EU	
	Water resilience techniques		IT and EU	
	soil management		Study area	
Co-Development meetings		Demo farmers	IT	see also Deliverable "*Report on Co-Development activities"*
Living Labs field visit		Living Labs	IT	see also Deliverable *"Report on activities to increase stakeholders' awareness"*
Living Labs Webinar		Living Labs	IT and EU	
Dissemination events		Farmers Technicians Agronomist	IT	
Final Conference		Farmers Technicians Agronomist Researcher	IT	
Vine performance and environmental data				see also Deliverable *"Report on the effectiveness of resilience strategies in DEMO farms."*
Monitoring tool evaluation			IT and EU	see also Deliverable "*Report on the Monitoring Tool evaluation*"

Results

A SWOT table was made for each proposed technique and the Monitoring Tool – PocketDRIVE App. In the following table a short introduction to each "SWOT letter" is reported.

STRENGHTS	WEAKNESSES
the positive attributes and resources that the technique has or can leverage	**the negative aspects and gaps of the technique that need to be improved or overcome**
OPPORTUNITIES	**THREATS**
the external factors and trends that the technique can benefit or that can create new possibilities	**the external factors and risks that can harm the technique application.**

Monitoring tool – PocketDRIVE

STRENGHTS	WEAKNESSES
- Easy to use - Intuitive - One tool with multiple functionalities - Smartphone app not requiring the use of expensive scientific instruments	- Currently developed exclusively for Android - Cultivar-specific calibration curves (between stomatal conductance and synthetic parameters of 3D leaf angle distributions) needed for water stress diagnosis. Currently available for cvs. Malvasia di Candia Aromatica, Croatina, Pinot Noir, Pinot Blanc, Sangiovese, Montepulciano, Chardonnay
OPPORTUNITIES	**THREATS**
- Usable by agronomist/technicians for vineyard monitoring and consulting - Usable by farmers/technicians to assess grapevine water stress triggering emergency irrigation schedules - Useful for monitoring water stress occurrence to identify vineyard sensitivity to drought	- Several tools are already available on the market for supporting winegrower's decisions. It is necessary to adopt a proper market strategy aimed to emphasize the innovative aspects of the technology for supporting the presentation and commercialization.

Green manuring (GM):

STRENGHTS	WEAKNESSES
- Well-known technique to integrate organic matter into the soil and to increase soil fertility (mineral and microbial diversity). - Increase of water holding capacity - Improvement of water infiltration - Improvement of soil physical properties - Legumes fix Nitrogen - Weed control - Increase of beneficial insects - Reduce some pests and diseases	- The choice of the best and appropriate mixture in terms of floristic composition and C/N ratio needs attention. - Cover crops must be timely sown to guarantee fast soil cover - Biomass production is strictly dependent on weather conditions between seeding and termination. - Effects on the vineyard's water resilience are not very pronounced

	- Additional costs due to seed purchase, sowing and biomass termination
OPPORTUNITIES	**THREATS**
- Good choice also for other crops - High transferability to farms with different size and pedoclimatic contexts.	- Effects on the soil fertility become consistent over time - Soil condition (moisture) at the time of biomass burial - Difficulty in biomass burial in skeletal soils - EU CAP Ecoscheme limitations

Between-row mulching (R):

STRENGHTS	WEAKNESSES
- Timesaving in vineyard management (not requiring repeated interrow mowing over the season) - Allows the execution of vineyard management before biomass termination. Lower soil erosion and compaction (reduced machinery impact) - It might solve an issue of water logging - Effective mulching may contribute at lowering soil temperature, reducing weed growth and ET rates. - The roller width may be hydraulically adjusted for adaptation to different operational conditions (i.e. row spacing). - High operational speed - Legumes fix Nitrogen - Increase of beneficial insects - Reduce some pests and diseases -	- Cover crops must be timely sown to guarantee fast soil cover - Biomass production is strictly dependent on weather conditions between seeding and termination. - A good uniformity and abundant biomass at termination is crucial for the successful implementation of the technique. - High costs for seed purchase, sowing and biomass termination. - Good fit between row spacing, sown strip and roller width is necessary for a good result. - The roller requires appropriate setting and weight - No pruning residuals should be present when rolling the biomass (a winter mulch is required in case of application of the technique every interrow; pruning residuals should be pulled off and localized in the “free” interrow in case of rolling every second row)
OPPORTUNITIES	**THREATS**
- Market interest for “Crimper rollers” - Relatively cheap equipment either for private users and contractors.	- Potential native vegetation regrowth in case of insufficient deactivation of the grass stems - Not applicable in vineyards that are difficult to access - Within-field variation of soil properties may negatively affect cover crop development resulting in heterogeneous biomass production.

Piling of mowed interrow grass under the row ("mow and blow") (SR):

STRENGHTS	WEAKNESSES
- Effective at preserving higher soil moisture in the under trellis top layer. - In case of moderate to severe water stress, it tends to maintain a less negative pre-dawn leaf water potential. - Effective weed control (in case of abundant biomass uniformly covering the soil) - Sustainable weed control in the under the vine strip - Fully mechanizable - Pruning residuals may be intercepted by the machinery during termination contributing at increasing the biomass coating in the under the vine strip - Increase of water holding capacity, water infiltration and soil physical properties - Legumes fix Nitrogen - Increase of beneficial insects - Reduce some pests and diseases	- The cost of "mower-conditioner" machinery needs to be negotiated depending on custom-rental or vineyard size, if purchasing is planned. - Problems in managing operations such as mechanical desuckering (the operation may be easily applied manually or with chemical solutions). - Early-spring herbicide application in the under-the vine strip is recommended before termination especially when establishing the mulching cover. In organic vineyard the weed control may be done mechanically or by using hand-held grass trimmers. - Not applicable in vineyards that are difficult to access - Operational challenges in high-density vineyards due to reduced inter-rows spacing. - Cover crops must be timely sown to guarantee fast soil cover - Biomass production is strictly dependent on weather conditions between seeding and termination. - Good fit between row spacing, sown strip and mulcher width is necessary for a good result. -
OPPORTUNITIES	**THREATS**
- Sustainable weed management in the under the vine strip, in line with the need of reducing herbicides and reiterated tillage in agriculture. - The cover will strengthen over years becoming more permanent and likely improving its weed control function.)	- Not applicable in vineyards planted on steep slopes or where machine transit is impeded or difficult (for instance narrow spacing between rows) - It is necessary having abundant biomass at the time of termination for the successful implementation of the technique. - It might be difficult to be implemented having low potential for active grass growth in spring.

Sowing and transplanting of ground cover species under the rows

STRENGHTS	WEAKNESSES
- Reduced water and nutrient competition toward the neighbouring vines - Effective sustainable weed control through natural based solutions - Reduction or elimination of vineyard management operations such as ploughing, mowing and herbicide application in about 25-30% of the vineyard - Low maintenance needs - No physical damage to vine trunk and graft union.	- High establishment costs especially when transplanting is needed. Mechanical solutions are still uncommon and/or unavailable on the market - Difficulties in grass cover establishment which aggravate as a function of soil moisture at spring and degree of competition from native species. -
OPPORTUNITIES	**THREATS**
- Sufficient knowledge to expand the application in other geographical contexts. - Technique already tested in other countries (e.g. France and Spain). Results and knowledge achieved in other countries from the Mediterranean Basin could be transferred for facilitating the development of operational protocols.	- Under the vine irrigation may promote the establishment of the soil cover - Seedbed must be prepared in advance to maximise the probability to get prompt soil cover (weed free, softness, etc.) and to lower operational costs. - For optimal results, it is necessary to choose the best cultivars for sowing/planting according to site features.

Kaolin

STRENGHTS	WEAKNESSES
- Clear and immediate effects (short term solution) - Recommended in vineyards prone to light and thermal stress - Low costs - Reduction of berry sunburn and maintaining of leaves physiology activity under severe water stress. - Easy to be applied - Known to be washed off by moderate to heavy rain - Maintenance of yield and grape quality - Side effects on pest control	- Difficulties in determining the best timing of application - Upon application, it can be washed off by fairly intense rain (> 15 mm) and a second application might be needed
OPPORTUNITIES	**THREATS**
- Equipment (sprayers) already available in farms	- Needs of broader dissemination of positive effects among growers. - Possible (but not confirmed yet) interferences of kaolin residues on the winemaking process.

Discussion and final remarks

The PocketDRIVE app

The developed PocketDRIVE app has been appreciated by farmers, but even more so by technicians who see it as a tool that can support the monitoring and consulting activities of their clients' vineyards. The main obstacle is the limited usability, restricted, for now, to Android smartphones. However, in the after-life period, at the time of commercialization, a version for iOS will also be developed based on the final version released. In the after-life period new varieties will be added to ensure a wider usability in other geographical contexts. The market strategy, supported by UNIMI and Cassandra LAB, will have to compete with the numerous smartphone products (DSS) already available in the market. Therefore, it will be crucial to identify the right targets and the best channels to communicate the innovative aspects of the app.

The Water Resilience Techniques (WRT)

According to the presented SWOTs some common elements could be highlighted and commented,

STRENGHT	WEAKNESSES
- Promising effects - Soil quality improvement - Soil water retention improvement - Field activities optimization - Positive effects on soil ecosystem services (water holding capacity, water infiltration, reduction of some pest diseases and increase of biodiversity) and soil physical properties.	- Costs - Timing of management operations (sowing, termination) and dependency on weather trends. - Need for abundant biomass - Difficult to be applied in vineyards with low tractor accessibility. - Cover crops must be timely sown to guarantee fast soil cover - Biomass production is strictly dependent on weather conditions between seeding and termination.
OPPORTUNITIES	**THREATS**
- Sustainability (inputs reduction)	- Specific machineries not always available - Adoption of correct seed mixture for effective results - Intra-farm and intra-vineyard variability

Insofar, few differences have been observed in terms of grape yield/composition response, as well as vigor. In fact, it is known that in a perennial crop like the grapevine, time is needed before the effects on the root system will have consequences on the behavior of the above-ground part. (More details on effectiveness can be found in the Deliverable "***Report on the effectiveness of resilience strategies in DEMO farms***")
Biomass, a key factor for the success of R, SR and GM techniques, is strongly influenced by:
- Soil composition and identification of most appropriate seed mixture
- Water/nutrients availability during cover crop growth (germination-termination)
- Sowing and Termination date
- Climatic trends

- Intra-farm variability

The analysis of responses to the questionnaire submitted to farmers in the study area (Colli Piacentini and Oltrepò Pavese) has highlighted that 60% of respondents have modified their soil management protocol in the vineyard over the last 3 years (in the row, between rows, or both). The motivations behind this decision are mostly related to the decrease in available water and the increase in **drought,** and their effects on grapevines performances including fruit composition and yield.
The dissemination of project results and guidelines for the application of the proposed “WRT” will support the reduction of evident effects of climate-change in the project area.
However, limitations to the application of techniques are also undeniable, partly classifiable as the perception of the grower, such as the costs of seeds and operations. These costs need to be assessed compared with the optimization of field activities following a different distribution of the workload that the techniques require.
The local availability of specific machineries required for establishing the nature-based solutions as well as for their management and termination when required (i.e. in case of GM, R and SR) remains an obstacle that only widespread adoption of the techniques can eliminate, based on the "demand and supply" rule guiding the market.

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