OBJECT: manuscript ID soil-2014-43 entitled " An overview of the recent approaches for terroir functional modelling, footprinting and zoning" submitted to the SOIL journal.

Firstly, we would like to thank Anonymous Referee#2 for helpful comments. We have extensively revised the paper based on his/her suggestions. The list of specific points and how we address them in the review article is below.

Anonymous referee #2: "The manuscript is an overview of existing data and modelling approaches for terroir functional modelling, footprinting and zoning at local and regional scales. The paper address relevant scientific issue within the scope of SOIL. The paper address soils within a multidisciplinary context and it is of broad international interest- The objectives are not very clear, especially it is difficult to find a correspondence between the objectives written in the abstract and the discussion. Moreover the relationship between the soil and the production and / or product quality is not widely explained. The paper is not concise, In my opinion some parts could be reduced."

"The objectives are not very clear , especially it is difficult to find a correspondence between the objectives written in the abstract and the discussion."

***Our reply to that comment:***
*Both anonymous referees share the critic that the paper is rather long and not well-organized because too many objectives are treated and that the reader would have expected to know more about relationships between soil and vine features. Possibly the critics come from the fact that relationship between soil and wine, which is at the basis of the terroir concept, is not yet fully acknowledged by the scientific consortium and must be further documented. For this reason and in order to clarify the reading of this paper, we followed the Anonymous Referee#2's suggestion of reducing some parts of the manuscript.*

***How this is implemented in the revised manuscript:***
*The manuscript was reduced to the following sections corresponding to the most original objectives highlighted by Anonymous Referee#1:*
*1/ New tools for assessing terroir footprints: metabolomics, metagenomic approach and microbial/chemical fingerprinting,*
*2/ terroir zoning at different scales: mapping terroirs and using remote and proxy sensing technologies to monitor soil quality and manage the crop system for a better food quality*
*The last section about terroir sustainability was reduced but maintained because we considered it as a perspective deriving from the new tools developed.*
*We added a new figure 1 in the first part (please see the attached supplement file).*

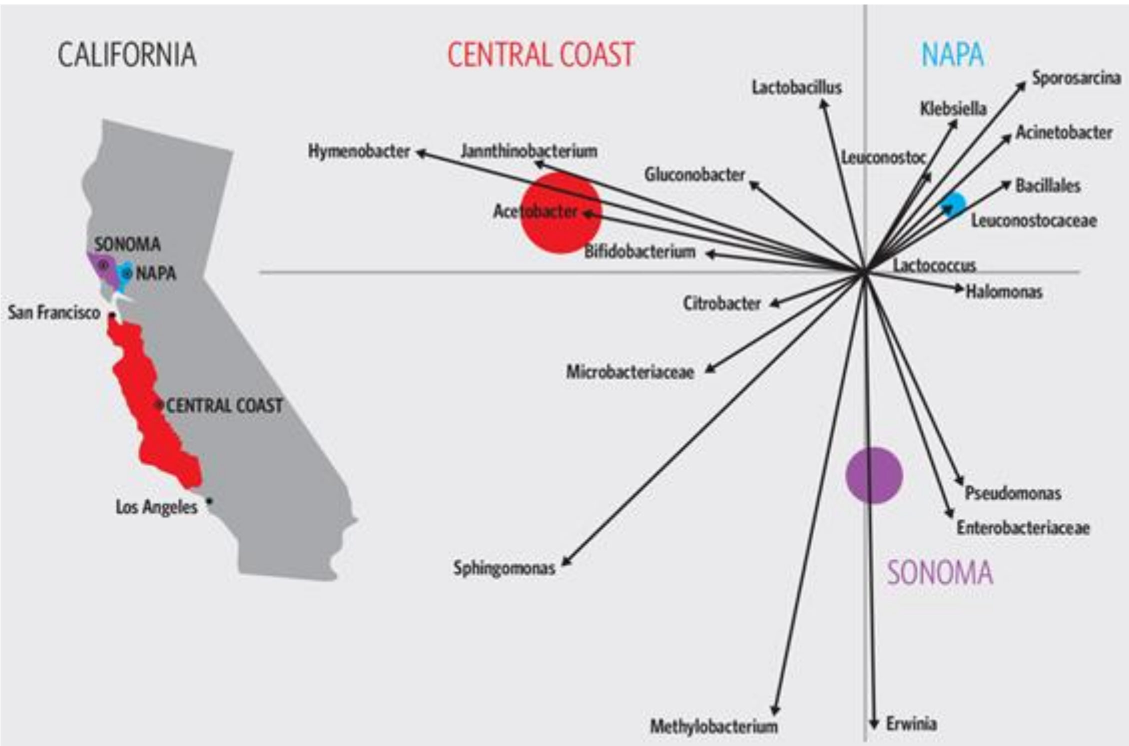


Figure 1. Differences in grape surface microbial communities present between wine regions of California. From: https://cosmosmagazine.com/earth-sciences/winemaking-art-or-science

Anonymous referee #2: “Moreover the relationship between the soil and the production and / or product quality is not widely explained.”

***Our reply to that comment and how this is implemented in the revised manuscript:***
*This objective was dropped as suggested by Anonymous Referee#1.*

Anonymous referee #2: “The paper is not concise, In my opinion some parts could be reduced.”

***Our reply to that comment and how this is implemented in the revised manuscript:***
*This is what we did: the text was significantly reduced and only parts dealing with chemical/biological footprinting then dealing with zoning were developed.*
*A new table 2 was provided as recommended by Anonymous Referee#1 (please see the attached supplement file, page 4)*

Anonymous referee #2: “The figure 1 is not significant of the increase of the importance of terroir in publications. I’m quite sure that in general the number of papers published each year is increased from 1990 to 2014. It could be more interesting to make a graph with “number of paper using terroir term/number of paper regarding viticulture”

***Our reply to that comment:***
*Figure 1 was dropped and Figure 2 maintained.*
*We did not consider “ number of paper using terroir term/number of paper regarding viticulture” as suggested because this review was not specifically focused on viticulture but also related to soil*

*research".*

***How this is implemented in the revised manuscript:***
*Figure 1 was dropped and Figure 2 maintained.*

`Anonymous referee #2:` "The first part of page 839 is confuse"

***Our reply to that comment and how this is implemented in the revised manuscript:***
*This section was removed.*

`Anonymous referee #2:` "Page 864 explain the acronyms"

***Our reply to that comment and how this is implemented in the revised manuscript:***
*OK acronyms were explained.*

`Anonymous referee #2:` "The paragraph 4. Improve The order of the paragraphs in the section 4. Regard the effect of alternative management to control erosion in Mediterranean , see Ruiz Colmenero et al., or Novara et al., (2011)"

***Our reply to that comment and how this is implemented in the revised manuscript:***
*OK Ruiz-Colmenero et a., 2011, 2013 added but we did not include that by Novara et al. (effect of vineyard abandonment on soil organic carbon dynamics) in order not to develop the third section "perspectives" excessively (as a matter of fact, Anonymous Referee#1 suggested to drop this topic, which we nevertherless maintained, as an opportunity enabled by the new zoning approaches).*

Table 2. Typology of zoning studies carried out over the 2002-2014 period

| Targets | Scale | Data | Methods | Pros | Cons | References (e.g.) |
|---|---|---|---|---|---|---|
| Grape composition | plot | FM | BK then FA followed by Fuzzy KM | Fine-scale | Time-consuming, high sampling density (3 m) | Baluja et al. (2013) |
| | plot | FM, airborne NDVI | LR | Fine-scale spatially exhaustive data | Specific calibration for each plot | Lamb et al. (2004), Hall and Wilson (2013) |
| | plot | FM, Fluo and/or airborne NDVI, ChloM | Spectral index, CF | Replaces expensive measurements | Need of specific calibration for each plot? | Ben Ghoslen et al. (2010), Baluja et al. (2012b), Agati et al. (2013) |
| | district | VIS-NIR HypS airborne imagery, FM | Spectral indices, LR | Fine-scale spatially exhaustive data | Specific calibration for each plot | Martín et al. (2007), Meggio et al. (2010) |
| | region | FM, VIS-NIR-SWIR HR satellite imagery, TopoP and/or soil map | Multitemporal SC, SA | Large-scale spatially exhaustive data, landscape-scale relevant for unions of winegrowers | Spatial resolution of imagery appropriate if homogeneity of practices | Vaudour (2003), Vaudour et al. (2010, 2014) |
| Canopy characteristics, yield and grape composition | plot | FM, YM | OK then KM and/or LOGR and/or NPT | Fine-scale | Time-consuming, high sampling density (2 m) | Bramley and Hamilton (2004), 2005 ; Tisseyre et al. (2008); Bramley et al. (2011a), Arno et al. (2012) |
| | plot | FM (including CC), soil ECa, TopoP | NDVI, Fuzzy KM, correlations | Fine-scale | Need of further validation | Tagarakis et al. (2013) |
| | plot | FM, VHSR satellite NDVI | Fuzzy KM and/or GK, ANOVA and/or PCA and/or NPT | Early grape composition, definition of harvest zones | Spatial resolution of imagery not quite appropriate ? | Martinez-Casanovas et al. (2012), Urretavizcaya et al. (2013) |
| | plot | FM, airborne NDVI (0.3 m) | Correlations | Easy-to-use, spatially exhaustive data | Specific calibration for each plot | Hall et al. (2011) |
| | farm | FM (including $\delta^{13}C$) , airborne NDVI, soil ECa, TopoP | WHC, ANOVA, IDW thresholding | Relevant scale for winery, good compromise data collection/results | Need to test feasibility at the winery scale | Santesteban et al. (2013) |
| | farm/ district | FM (LAI), VSHR satellite NDVI | LR | Easy-to-use, spatially exhaustive data | Specific calibration for each image, spatial resolution of imagery not adapted to every viticultural system | Johnson et al. (2003) |
| | district | VIS-NIR HypS airborne imagery, FM (including leaf LabR spectra) | LR, spectral indices, inversion of PROSPECT-rowRCRM model for predicting leaf reflectance | Fine-scale spatially exhaustive data | Complex parameterization | Zarco-Tejada et al. (2005) |

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|---|---|---|---|---|---|---|
| | region | FM, soil map, TopoP, daily climatic data | SWAP mechanistic model | Landscape-scale relevant for unions of winegrowers | Needs detailed data at specific sites for parameterization | Bonfante et al. (2011) |
| Yield, oenological parameters | plot | FM, YM, soil ER, airborne NDVI and/or topographic parameters | OK and/or PCA then KM | Fine-scale, whole soil-vine-wine chain considered | Time-consuming, high sampling density (≤ 2 m), multisensors collection, microvinifications | Bramley et al. (2011c, d), Priori et al. (2013) |
| Biomass, oenological parameters | plot | FM, airborne NDVI | NDVI thresholding, then LR | Fine-scale | Time-consuming, high sampling density (5 m) | Fiorillo et al. (2012) |
| Yield, vine trunk circumference | plot | FM, soil ER, TopoP | LR, Fuzzy KM, ANOVA | Fine-scale | Time-consuming data collection | Rossi et al. (2013) |
| Vine trunk circumference, management zones | farm | FM, airborne NDVI | Spatially constrained KM | Manageable zones | Need of effective testing of the aggregation-component of the algorithm | Pedroso et al. (2010) |
| Vine water status | plot | FM (including PLWP), airborne NDVI | NDVI thresholding, LCCAOT | Temporal stability of the zoning over 3 years | One soil type considered, specific calibration for each block required | Acevedo-Opazo et al. (2010a) |
| | plot | FM (including $\delta^{13}$C and SWP) | LR, NPT, LCCAOT, IDW thresholding | High validation performance | Specific calibration for each block required | Herrero-Langreo et al. (2013) |
| | plot | FM (PLWP or SWP), VIS-NIR MS and thermal UAV imagery | Spectral indices, LR | | Specific calibration for each plot required | Baluja et al. (2012a), Bellvert et al. (2014) |
| | farm | FM (including PLWP), airborne NDVI, soil ER | NDVI thresholding, PCA, NPT | Temporal stability of the zoning over 3 years | Auxiliary information on soil types needed | Acevedo-Opazo et al. (2008) |
| | district | FM (PLWP) | LCCAOT, LR | Easy-to-apply for winegrowers | Need of further validation | Baralon et al. (2012) |
| Vine rows | plot | Airborne NDVI | VineCrawler algorithm | Suited for vineyards with large rows/interrows | Not suited for dense low-vigour vineyards with missing vines | Hall et al. (2003), |
| Vineyard identification, vine rows, and vineyard characteristics | plot | FM (LAI), VIS multiangular UAV imagery | SfM, multiple regression | Promising ; 3D-reconstruction | Big data ; further improvements needed to improve LAI prediction | Matthews and Jensen (2013) |
| | district | VIS-NIR MS ULM or airborne imagery | TA, FT and/or « object-classifier » | Easy implementation, high processing speed, limited amount of parameters, export into GIS shapefile format | Further validation needed for detecting missing plants, further use of all spectral information | Rabatel et al. (2008), Delenne et al. (2010), Puletti et al. (2014) |

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|---|---|---|---|---|---|---|
| | district | FM, airborne LIDAR | Georeferencing, LR and/or KM, TA | Performing, 3D-reconstruction | Need of further test on complex viticultural landscapes with several training modes? Cost-prohibitive repeated acquisitions | Llorens et al. (2011), Matthews and Jensen (2012) |
| | region | VIS MS helicopter imagery | FT, TA | Robust recognition of vineyards | Ambiguities in identifying training modes | Wassenaar et al. (2002) |
| | region | VHSR MS satellite imagery | TA, autocorrelogram pattern | Robust recognition of vineyards | Better adapted to equally spaced vineyards with large rows | Warner and Steinmaus (2005) |
| | region | MR MS satellite imagery | Multitemporal SC | Fast unexpensive landscape-scale map | Not accurate enough at the farm/plot scales | Lanjeri et al. (2004), Rodriguez-Perez et al. (2008) |
| Soil properties, potential management zones | plot | Soil ECa and/or ER, FM (soil analysis) and/or airborne/satellite NDVI | FKA, KM | Additional description of residual variation within classes provided | Ground-truth soil samples mandatory to understand + interpret EMI mapping | Morari et al. (2009), André et al. (2012), Andrenelli et al. (2013), Martini et al. (2013), Priori et al. (2013a) |
| | farm | Soil ECa, soil map | Geostatistical descriptors, FA | Satisfactory discrimination between soil types | Reference soil map needed in addition to ECa | Taylor et al. (2009) |
| | region | FM (clay content), airborne VIS-NIR-SWIR HypS imagery | CR, coK, BcoK | Spatially validated | Further test on other soil types/cultural practices | Lagacherie et al. (2012) |
| | region | FM (soil types, analyses), TopoP, geological map, soil map and/or climatic data | GIS combination of raster layers and/or PCA and/or KM | Landscape-scale relevant for unions of winegrowers ; | Need of further spatial validation; potential high number of output map units | Carey et al. (2008), Herrera-Nuñez et al. (2011) |
| | region | FM (soil types, analyses), TopoP and/or satellite HR imagery | Different geostatistical models, SC, PCA, fuzzy KM | Landscape-scale relevant for unions of winegrowers ; spatially validated | Need of further viticultural characterization + validation | Hugues et al. (2012), Malone et al. (2014), Priori et al. (2014) |
| Soil surface condition | plot | FM (soil infiltration rate, clod sizes), VIS UAV imagery | SC, multiscale « object-classifier » | Enables to avoid time-consuming field descriptions | Possible improvements considering NIR and SWIR ranges | Corbane et al. (2008) |
| | region | FM (BRDF), VIS helicopter imagery | TA, BRDF model | Extraction of bare soil inter-rows | Possible improvements considering NIR and SWIR ranges; need of further validation | Wassenaar et al. (2005) |

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|---|---|---|---|---|---|---|
| Erosion | plot | FM (SUM), TopoP, historical landuse maps and/or soil ER,and/or VIS UAV imagery | KM, multitemporal SA | Fine-scale spatially exhaustive data | Further developments at a higher scale; time-consuming observations | Brénot et al. (2008), Paroissien et al. (2010), Chevigny et al. (2014), Quiquerez et al. (2014) |
| | region | FM (SUM), TopoP, historical landuse information | multitemporal SA | Variability of multi-decennial erosion across local and regional scales with acceptable investigation costs | Time-consuming observations | Paroissien et al. (2010) |
| Evapotranspiration | region | FM (EdCov, soil water), VIS-NIR-SWIR-thermal satellite imagery | HYDRUS-1D model, S-SEBI and WBI models | accuracies between 0.8 $mm.d^{-1}$ and 1.1 $mm.d^{-1}$compatible with applications | Further need to address model sensitivities , inclusion of row orientation, landscape characterization | Galleguillos et al. (2011a, b) |

Legend: BcoK, block co-kriging; BK, Block kriging; CC, crop circle sensor canopy measurements; BRDF, bidirectional reflectance distribution function; CF, curve fitting; ChloM, chlorophyll content measurements on leaves (chlorophyll meter) ; CoK, co-kriging; CR, continuum removal; Eca, apparent electrical conductivity; EdCov, eddy covariance measurements; EMI, electro-magnetic induction; ER, electrical resistivity; FA, factorial analysis; Fluo, fluorescence proxy measurements in the field; FKA, factorial kriging analysis; FM, field measurements at point locations; FT, Fourier Transform; GK, global kriging; GPR, ground penetrating radar; IDW, inverse distance weighting; HR, high spatial resolution; HypS, hyperspectral; KM, k-means clustering of interpolated values; LabR, laboratory reflectance spectra; LAI, leaf area index; LCCAOT, linear coefficient of correlation analysis and covariance analysis between sites over time; LR, linear regression; LOGR, Logistic regression; MR, medium resolution; MS, multispectral; NPT, non-parametric test; OK, ordinary kriging; PCA, Principal Components Analysis; PLWP, predawn leaf water potential; rowRCRM, Markov-Chain Canopy Reflectance Model; SA, spatial analysis; SfM, structure from motion; SPE, stereoscopic photograph examination; SUM, stock unearthing measurement; SWIR, shortwave infrared; SC, supervised image classifiers (such as regression trees, support vector machines, Bayesian Maximum Likelihood); SWAP, soil-water-atmosphere plant model; SWP, stem water potential; TA, textural analysis; TopoP, topographic parameters (mainly elevation, slope and/or topographic wetness index); UAV, Unmanned aerial vehicle; ULM, ultra-light motorized; VHSR, very high spatial resolution; VIS-NIR, visible and near infrared; WHC, Ward's Hierarchical Clustering; YM, yield maps from grape harvester equipped with yield monitor.