Land evaluation in areas with high environmental sensitivity and qualitative value of the crops: the viticultural and olive -growing zoning of the Siena province.

Edoardo A.C. Costantini, Lorenzo Sulli
Istituto Sperimentale per lo Studio e la Difesa del Suolo, Firenze, www.issds.it/cncp

Summary
In Italy there is a tendency to delegate most of the authority concerning agricultural matters, especially the ones respecting land planning and expenditure policy, to the Provincial Administrations. As Provincial Administrations seldom have all the technical expertise necessary to carry out this function, they usually rely upon free-lance professionals or Universities and Experimental Institutes. The Provincial Administration of Siena assigned the Istituto Sperimentale per lo Studio e la Difesa del Suolo of Florence the task of studying the possibilities of extending viticulture and olive tree cultivation in its territory, while at the same time safeguarding eco-compatibility, namely soil conservation, and the quality level of the products. A methodology was therefore worked out, aimed at evaluating the crop suitability of the Siena territory. This methodology requires a reasonable amount of time, is scientifically sound and can be easily applied by other Provincial Administrations.
Its main qualifying aspects are the following:
i) the political and technical staff of the Administration were from the very beginning involved in defining the goals and ground rules of the study, i.e. study area, scale of investigation, meaning of the term "suitable".
ii) The study was completely computerised and compatible with the Provincial Territorial Information System.
iii) The term crop eco-compatibility was not only considered in the sense of avoiding excessive soil erosion, but also in the se nse of preserving soil qualities, e.g. land capability, runoff regulation, soil suitability for producing high quality yields.
iv) The soil suitability was evaluated with reference to specific agronomic models and using a geographic database.
v) The evaluat ion was calibrated and validated with experimental plots.
vi) To assess crop requirements and soil functional characters it was set up a multidisciplinary collaboration, with researchers belonging to the different disciplines involved.
vii) In order to generalise soil information, two aspects were taken into account: how to group point information and allocate it to a soil typology, and how to extend point information to map units.
viii) Land Evaluation maps were completed with an explicit explanation of the inferences made in the evaluation process. Three indices were proposed: the “reliability” of the relationship between soil landscape; the "confidence" of the soil suitability and the “accuracy ” of cartographic information.
The initial outcomes of the work indicated that the areas in which it is possible to combine complete eco compatibility and top quality production are very limited, with the current state of technology. Thus, although the study demonstrated a fair potentiality for the expanding of the two crops, the plantation and husbandry techniques would have to be modified and improved, with the adoption of appropriate soil conservation practices, specially designed to suit each site.

Introduction
On the basis of an Italian law, i.e. law 142 of 1990, regarding local government reform, several Regional Administrations are tending to delegate most of the authority on land planning and expenditure policy in the agricultural sector to the Provinc ial Administrations, and the region of Tuscany is very much in the forefront terms of the delegation of this authority (viz. regional law 5/95). With precisely that low in mind, in its plan agricultural land development, the Agricultural department of the Provincial Administration of Siena, decided assess the possibilities of extending

viticulture and olive growing in the area, safeguarding of course the eco compatibility of the crops, especially against soil erosion. The Administration is going to use this information define new designated origin areas for t hose agricultural products.
The Istituto Sperimentale per lo Studio e la Difesa del Suolo of Florence has been working on the links between soil and product quality for more than twenty years (Lulli *et a*l., 1980; Costantini *et a*l., 1985) and the lynch for the methodological development has been the vine.
We moved on from studying the relationships between soil and crop yields (different soils = different grape yields; Costantini, 1987) to the correlation between soil and quality of the wine (different soils = different wine quality; Lulli *et a*l., 1989; Costantini *et a*l., 1990; Costantini *et a*l., 1991). We then compared soil and wine components, in order to provide information about the best agricultural husbandry (different soil functional characters = different wine sensorial profiles and yield components; Arcara *et a*l., 1993; Costantini *et al* Falcetti *et a*l., 1998; Falcetti *et a*l., 1999). Further studies regarded the interpretation of the data for viticultural zoning, according to different levels of soil parameter generalisation (Costantini, 1999). Finally, with the Province of Siena case study, we worked out a methodology to assess the territory, which would allow us to improve the local land planning policies, as well as those of the other Italian Provinces in general.

Methodological assumptions of the research, materials and methods

Established goals and ground rules

In order to meet the requirements of the Provincial Administration, it was first of all necessary to define the precise objectives of the research. This initial phase was managed in close co-operation with the technical and political staff of the Province. The first point we had to clarify was the area to be covered by the study. It was decided to consider the whole provincial territory, except the traditional areas of vine cultivation (communes Chianti and S.Gimignano, Montepulciano, Montalcino).
Another decision that was taken had to do with the degree of precision of the survey. This was very important, because the message we wish to convey with this study is that you cannot draw conclusions for individual agricultural properties, but rather assess the probability of finding soils, which are suitable for vine and olive cultivation inside different areas, in the shortest time possible. Hence the scale chosen was 1:100,000, which corresponds to the reconnaissance level.
We then went on to decide what we meant with the general term "suitable". It has been quite clearly established by our studies, as well as by many others in the world, that the control of the environmental factors influencing the quality of final products (in our case wine and olive oil) is only possible with detailed studies, and that agrotechniques and fruit processing can play a major role; this is especially true at the highest level of quality (Costantini and Campostrini, 1996; Lebon *et al.*, 1997; Champagnol, 1997). In other words, at reconnaissance level it is by no means possible to guarantee the quality of the products that can be obtained, in other words "the quality is in the hands of the farmers".
Finally, we reached an agreement on the meaning of the expression "suitable and eco-compatible" which was follow: "an area where there is a good probability of finding soils which can give sat isfactory yields, both in term of quantity and quality, most years, without particularly expensive agrotechniques and an excessive risk soil degradation, namely erosion".

The georeferenced soil database

One of the requests made by the Province was that our Soil Information System should be completely compatible with the Provincial Territorial Information System. In fact, although it is the Provincial Department of Agriculture which decides on the expenditure, general land planning is the responsibility of a different department, which deals with the storage and management of all the territorial information, including soils.
When studying agricultural practices that could have an environmental impact, the Land Planning Department needs to store all this information in their database. So, the databank we have set up utilises the software Access, Arcinfo and Arcview, the same software which is used by the Siena

Province. Within our databank, soil point information is organised in soil typological units and subunits, with a specific range of variation for each soil parameter (Gardin *et a*l., 1996). Actually, our strategy was to concentrate our efforts on the most complete and appropriate characterisation of the functional properties of soil typological subunits, in our case phases of soil series (UDSA, 1993).

How to evaluate soil suitability

In order to assess soil suitability, we decided to use agricultural reference models. At the present state of the these models have been developed for vine cultivation, rather than for olive trees. In particular, researchers have established that the oenological result of the plant corresponds to a specific plant growth and ripening model, which is determined by agricultural practices, climate and soil conditions. So each site can be evaluated according to the difference between the actual soil conditions and the ones of the agronomic model which coincides with the desired oenological result. The rationale is based upon the observation that environmental factors influence the hormonal equilibrium of each variety, which in turn regulates the expression of the genotype (Van Leeuwen and Seguin, 1997; Costantini, 1998). The Sangiovese vine, for instance, in the most fertile soils, i.e. the ones lacking permanent limitations, gives bad viticultural and oenological results, due to excessive productivity. On the other hand, better results can be obtained in quite fertile soils, but with some pedological limitations which induce a moderate stress. The least fertile soils, e.g. those which have been severely eroded, always produce less than the better preserved ones, but they give very variable oenological depending on the year (Campostrini and Costantini, 1996).

As reference varieties we chose the Sangiovese vine, the basic constituent of the most important wines of the area (Brunello di Montalcino, Chianti, Nobile di Montepulciano) and the widespread and highly rated Moraiolo olive .

How to establish crop "eco-compatibility"

To complete the land evaluation, we had to combine soil suitability with crop "eco-compatibility".

To define crop "eco-compatibility" we cannot avoid considering the development of Italian agricultural systems over the last few decades, and the consequences of the advent and diffusion of the so -called "unattended" and "free time" agriculture (Grillotti Di Giacomo, 1992). The former refers to the medium-large and large farms, which utilise high economic inputs and few workers, who are essentially involved in the productive process.

latter constituted by micro-landowners who occupy the rural spaces of settlements and infrastructures, but gravitate upon the city, and use agriculture as an essentially leisure-time activity. From the point of view of this rural territory transformation and agricultural social development, what we have the progressive disappearance of the traditional farmer way of life, with the constant presence of man on the and his awareness of the importance of soil conservation practices ("coscienza sistematoria"). As a consequenc also in Tuscany, and precisely in those areas where specialised tree cultivation is particularly widespread, we come up against a progressive transformation of the landscapes, where the most traditional ones, namely those characterised by stone or earth terraces ("terrazzamenti") and mixed culture ("coltura mista") are gradually disappearing. The modern model of land use, designed to suit agricultural machinery, has been generally applied, without considering soil properties and in many cases it has impaired soil qualities, e.g. land capability, runoff regulation, soil suitability to produce high quality yields (Costantini, 1992; Gregori *et a*l., 1999; Costantini *et a*l., in press). Thus, the vineyard and olive tree eco-compatibility in the Siena Province implied cultivation model which not only permitted avoiding excessive soil erosion, but which also preserved all these soil qualities. From a technical point of view, this meant that, during the evaluation process, we had to rate soil and land characteristics and set management and conservation requirements for the two crops according to the desired eco-compatible model.

Set multidisciplinary evaluation

The methodological assumptions entail a knowledge of the relationships between soil properties and crop behaviour. This is only possible with a field check of the crop performance in the different soil

conditions, as well as by means of an accurate characterisation of the soil functional parameters. For this reason, the research has involved several experts from other sectors: dr. Antonio Cimato of the CNR, Istituto sulla Propagazione delle Specie Legnose of Florence and his collaborators, drs. Simona Caselli, Lucia Tacconi and Ljiljana Petkov, researchers on olive growing, and drs. Paolo Storchi and Egon Egger, belonging to the Istituto Sperimentale la Viticoltura of Arezzo, researchers on vine growing. They have played an essential role by suggesting crop requirements in terms of soil and climate, as well as by providing data and information from the experimental plots set up inside the study area.

The aspects related to the characterisation of soil hydrological properties and structural stability have been investigated by drs. Sergio Pellegrini and Paolo Bazzoffi of the Istituto Sperimentale per lo Studio e la Difesa Suolo of Florence, while drs. Rosario Napoli and Lorenzo Gardin, of the same Institute, made a major contribution to the assessment of the architecture of the database (Napoli *et al.,* in press).

Data gathering, quality check and harmonisation

A large number of data were collected from different studies performed by the Istituto Sperimentale per lo Studio e la Difesa del Suolo, the Province of Siena and the Tuscany Region and this data had to be stored in Soil Information System. The standardisation and quality check of the information was a difficult and time consuming job, because it involved technical standardisation activities (codices of the attributes, geographic reference system), quality check of the information (photointerpretation, soil classification) and soil correlation (database of the soil series). As a reference, we took the codices of the ISSDS soil survey manual and software (Gardin *et a*l. 1998).

Generalising soil information

The next step was to assess the methodology for generalising the soil information. Two aspects were taken into account. Firstly how to generalise typological information, i.e. how to group point information and allocate it a soil typology, and secondly how to spatialise geographic information, i.e. how to extend point information map units.

The first aspect involved the creation of a catalogue of soil typological units and subunits. Thus, in our database, each soil observation has been referred to one soil unit and subunit, on the basis of soil classification, landscape characteristics and management requirements.

For the second aspect, we chose the Land System project of the Tuscany Region (Toscana. Dip. agricoltura e foreste, 1992), for the compatibility of scale, accessibility of informat ion and because we wanted to test a methodology that could be easily extended to all Tuscany and to the other regions as well.The main advantages of the Land System lie in its open structure, which allows the input of new items and enables us to provide codified geographic information, which makes it easier to link soils with their landscape, and permits a statistical sampling of the soils on a geographic base.

The main geographical components of the Land System methodology are Land Systems, Land Units and Elements. Land Elements are the smallest components, which can be recognised by the photointerpretation of characteristic geology, landform and land use pattern that can be described and codified, but not delineated on 1:100,000 map. Land Units are recognised and delineated, even by photointerpretation, through the recognition of a characteristic arrangement of Land Elements. Land Systems group Land Units together on a physiographic and geological basis.

The entire Province of Siena has been covered with the Land System approach, and every soil profile stored been referred to a Land Element. In this way, each Land Element typology may have a soil attribution, which constituted by one or more soil subunits.

As our soil database did not have a sufficient number of observations, we decided to carry out another field soil survey on several Land Element typologies, chosen from the ones which seemed most potentially suitable for vines and olive trees, in order to provide all the Land Elements for a soil qualification.

During the field survey, every soil observation followed the recognition of the Land Element typology to which it had to be allocated. Moreover, each observation recorded was preceded by

some auger holes (generally three or four) so that only the one which appeared to be the most representative of the studied typology was taken consideration. If a Land Element was constituted by different soils, the composition percentage was then recorded in the field file and subsequently in the database. Finally, soil information was transferred from Land Elements to map polygons, in order to produce thematic maps.

To sum up, each single map polygon belongs to one Land Unit and it is constituted by one or more Land Elements, each Land Element is constituted by one or more soil typological subunits, and every soil typological subunit has a set of observations (profiles, auger holes, mini pits) which are similar for soil classification, landscape, management requirements and crop suitability.

The evaluation process

The evaluation process took the territorial data into account first, and then the soil data. Right from the beginning, we excluded all the areas which the Tuscany Region considered to be prone to severe or very severe soil erosion, or to a very severe erosion risk, from the evaluation. We also left out water bodies and frequently flooded areas, quarries, urban settlements and dumps, all wooden lands and elevations higher than 600 m a.s.

The suitability of each Land Element was then established on the basis of its soil components, i.e. on each soil typological subunit present.

As the soil subunit contains several point information, we set up two expert systems, one for the vine and the other for the olive, which were able to evaluate each profile of the soil subunit on the basis of its functional parameters. The latter were taken from the previous studies (Costantini, 1987; Costantini e Lizio-Bruno, 1996; Campostrini *et a*l., 1997) and implemented in the software Access through specific algorithms.

A suitability class was attributed to every subunit by applying the expert system to all the observations referring to the soil and by taking the modal value of the resulting population; in some cases, when the population was limited in number, we took the value we thought to be the most representative.

Evaluating Land Evaluation

The Land Evaluation process is the estimation of the response of a given territory to a certain utilisation. Like classes of estimation, it is always affected by a certain degree of error, deriving from several sources. If it is not always true that the greater the inference the worse the result, nevertheless the degree of inference is seldom expressed explicit. This is a shortcoming of the Land Evaluation, because even if it is well known that political choices are not only based on technical aspects, however the users will maybe give more consideration to these aspects if they saw them as more reliable.

We tried to improve our Land Evaluation in three ways: i) by adding an experimental validation of the estimations, ii) by making the inferences we made in the evaluation process explicit; iii) by giving a geostatistical indicator of the exactness of the estimation.

As to the validation, we planned a series of experimental vine and olive plots to validate the effectiveness of predictions and to calibrate our expert systems. In the choice of the site, we gave priority to less known soils, soils where the cause-effect relationships between environmental conditions and crop response were not so well known.

We then worked out three indices regarding the uncertainty of the evaluation, in order to qualify the information provided with each map delineation. The purpose of the indices was not only to warn stakeholders against an over simplified use of the suitability map, but also to give information that would be useful for further, more detailed, investigations.

The first item we considered was related to the uncertainty about soil geography. In fact, our "soil paradigm" (Lulli e Costantini, 1992; Hudson, 1992) is based on the assumption that there should be a good agreement between soil geographic pattern, as evaluated by photointerpretation, and soil typology. For this reason we assumed that there should also be a certain degree of correspondence between Land Element and soil typological subunit. The first index therefore regards the “reliability” of this relationship. The index is based on the number and uniformity of observations

per Land Element: the higher the number of observations belonging to the same typology found in a certain Land Element, the higher the probability of having the actual presence of the soil which the evaluation has been made in a given map delineation.
In the showed map, only a first judgement in terms of "good" or "poor" reliability has been reported, but this estimation can be easily further refined. It is to be highlighted that the areas in which the soil paradigm fails often those where paleosols, or soil which have been deeply influenced by human activity, are widespread.
The second index refers to the uncertainty of the soil suitability. Actually, we made another "paradigm", i.e. soils with similar functional characters should give similar crop results. Thus, the more similar the soils on which evaluation is made are to the benchmark soils, i.e. the ones of the experimental plots, the higher the probability of having crop performance akin to the estimated one. The "confidence" index expresses a judgement on this similarity.
The third index refers to the "accuracy" of the cartographic information. It simply states the percentage of each polygon constituted by Land Elements with the estimated aptitude.
Finally, before the systematic survey, we took a set of auger hole observations, to be utilised at the very end the study, in order to compare the results of the evaluations performed on those sites using the Land Systems approach, with the ones obtained using the point soil characteristics taken. This will permit a geostatistical estimation of the effectiveness of the spatial generalisation methodology.

Initial results

Work is still underway, and the soil survey and most of the processing are not yet complete. However, to meet the specific request of the Provincial Administration, we drew up an initial draft of the two suitability maps at 1:100,000 scale.
In both maps there is a part which has been excluded, due to territorial limitations. This amounts to 57% and 49% of the total study area for vine and olive tree cultivation, respectively. A further 30% of the territory has soil information at yet. Of the remaining surface, 4.6% and 4.0% is covered by polygons with a "poor" suitability, i.e. a very low probability of finding soils with favourable characteristics for olive and vine cultivation. Another 6.9% for the vine crop, and 12.9% for the olive tree, are constituted by areas with "moderate" suitability, i.e. areas where it is possible to have soils with an acceptable agronomic result, but with limitations in yield, product quality (only wine considered) and with a considerable risk for soil conservation.
The areas where there is a high probability of finding "fairly good" soils cover 33,326 ha (12.0%) for the vine and 12,853 ha (4.6%) for the olive tree. If many of the soils of these areas are planted and cultivated with the
ordinary agro-technique, they provide better crop results and less environmental damage than the previous ones.
Finally, polygons with dominant soils of "good" suitability have only been found for olive trees at the moment, and they just cover 511 ha (0.2% of the whole territory). It should be pointed out that it was possible to find soils with good suitability, i.e. giving good quantitative and qualitative results and where the crop husbandry i eco-compatible, in other traits of land too, but they were too limited to be mapped at this scale.

Conclusions

The state of the art of the study does not allow us to draw final conclusions, nevertheless we can already supply the Provincial Administration with some information about the possible further diffusion of the two crops.
i) All in all, the area of the Province which was studied would appear slightly better suited to vine (18.9% of the study area) than to olive tree growing (17.7%).
ii) Both crops have a good diffusion potentiality, but the more profitable areas for vineyards are often the same as the ones for olive tree plantations, so there is a problem of competition between the two crops.

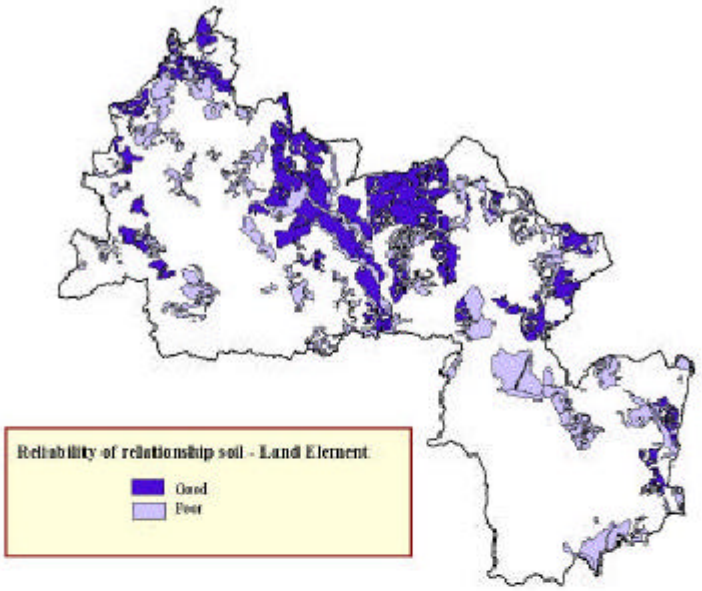
iii) Some vast areas, such as some belonging to the Siena, Poggibonsi and Colle Val d'Elsa communes, are fairly suitable for wine production. This suitability has already been acknowledged, and farmers can designate the origin of the wine ("Chianti dei Colli Senesi"). However, the same designation is not currently allowed for the same kind of wine produced in other areas, such as the communes of Asciano and Buonconvento, where it is possible to find soils having a similar suitability.
iv) A particularly relevant point is that the areas in which it is possible to combine complete eco compatibility and top quality production are very limited with the current state of technology. This is due to fact that the plantation and husbandry model normally used for these specialised crops causes environmental damage which is often not eco-compatible.
v) Therefore, there may be the potential for the expanding of the two crops, but if this is the case, the agro-technique has to be modified and improved, with the adoption of appropriate soil conservation practices.

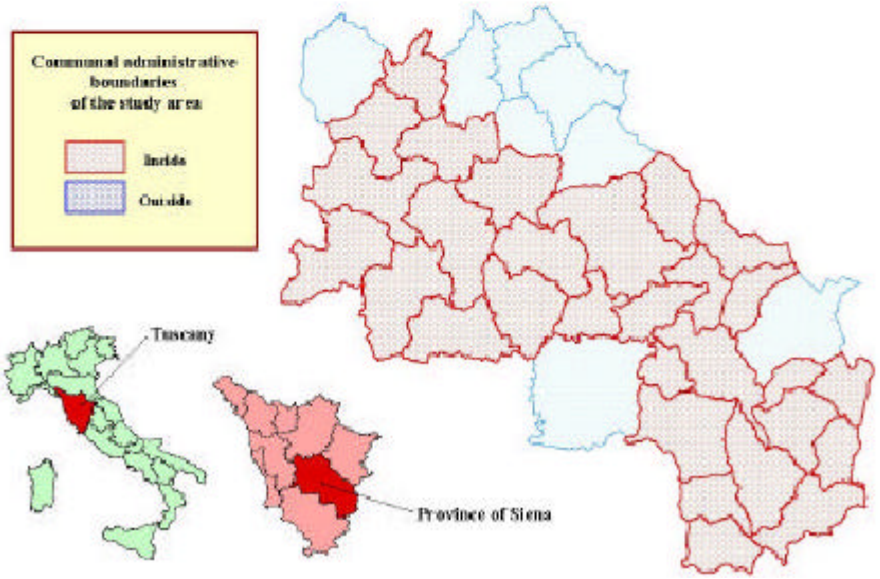
Acknowledgements
Authors acknowledge the work of the computer technician Mario Finoia of the Istituto Sperimentale per lo Studio e la Difesa del Suolo of Florence, who greatly contributed in the setting up of the Soil Information System.

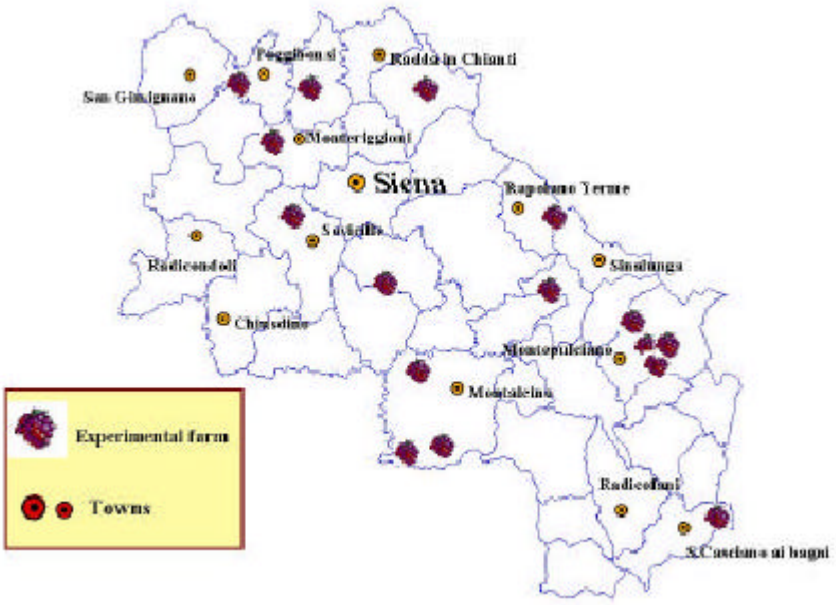
References
· Arcara P.G., Campostrini F., Cherubini P., Costantini E.A.C., 1993. Caratteri funzionali del suolo e risposta quantitativa e qualitativa del Vino Nobile di Montepulciano. Atti del convegno "La ricerca sperimentale corso per la viticoltura in Toscana" pp. 1-3.
· Campostrini F., Costantini E.A.C., 1996. Gestione del vigneto Nobile di Montepulciano per la valorizzazione delle risorse naturali del territorio. In: Vino Nobile di Montepulciano: zonazione e valorizzazione delle risorse naturali del territorio (F. Campostrini ed E. Cost antini ed.), Regione Toscana, Firenze, pp.110-120.
· Campostrini F., Costantini E.A.C., Mattivi F., Nicolini G., 1997. Effect of “Terroir” on quanti-qualitative paramethers of “Vino Nobile di Montepulciano”. 1er colloque international “les terroirs viticoles” Angers, France, INRA, pp. 461-468.
· Champagnol F., 1997. Caractéristiques édafiques et potentialités qualitatives des terroirs du vignoble languedocien. 1er colloque international “les terroirs viticoles”, Angers, France, INRA, pp. 259-263.
· Costantini E.A.C., 1987. Cartografia tematica per la valutazione del territorio nell'ambito dei sistemi produttivi. Bacini dei torrenti Vergaia e Borratello: area rappresentativa dell'ambiente di produzione del vino Vernaccia di San Gimignano (Siena). Ann. Ist. Sp er. Studio e Difesa Suolo, XVIII: 23-74.
· Costantini E.A.C., 1992. Study of the relationships between soil suitability for vine cultivation, wine quality and soil erosion through a territorial approach. Geoökoplus, III: 1-14.
· Costantini E.A.C., 1998. Le analisi fisiche nella definizione della qualità dei suoli per la valutazione del territorio. I Georgofili. Quaderni 1998 III. La normalizzazione dei metodi di analisi fisica del suolo. pp. 33-57.
· Costantini E.A.C., 1999. Soil survey and chemical parameters evaluation in viticultural zoning. Atti del convegno internazionale “zonazione viticola”. Ass. Naz. Città del Vino, Siena, pp. 485-492.
· Costantini E.A.C., Campostrini F., 1996. Vino Nobile di Montepulciano: zonazione e valorizzazione de risorse naturali del territorio. In: Vino Nobile di Montepulciano: zonazione e valorizzazione delle risorse naturali del territorio (F. Campostrini ed E. Costantini ed.). Regione Toscana, Firenze, pp. 9-14.
· Costantini E.A.C., Campostrini F., Arcara P.G., Cherubini P., Storchi P., Pierucci M., 1996. Soil and climate functional characters for grape ripening and wine quality of "Vino Nobile di Montepulciano". Acta Hort. 427 ISHS, pp. 45-55.

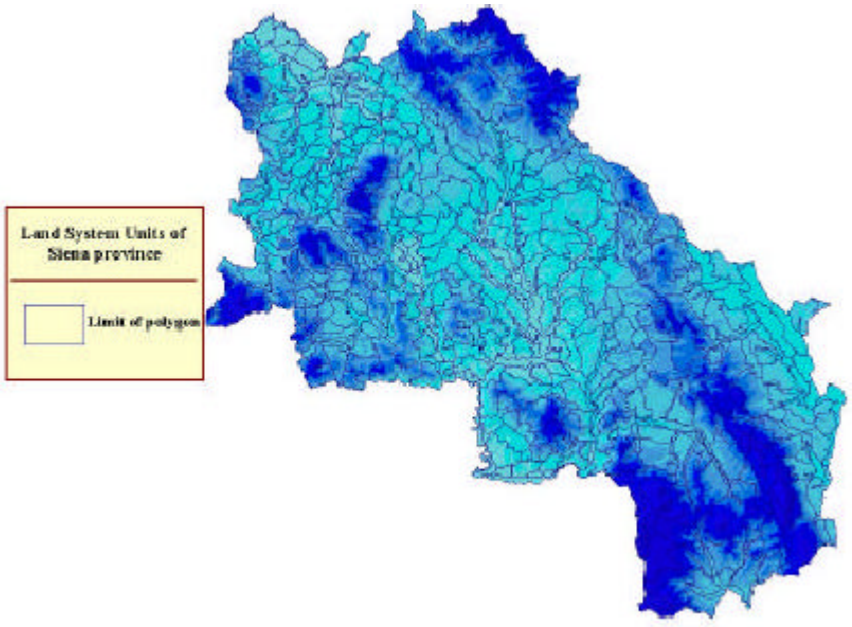
· Costantini E.A.C., Iori M., Gardin L., Gregori E., Napoli R., in press. Paesaggio culturale e qualità dei suoli nella collina toscana. Atti del convegno SISS di Ischia, 1998.
· Costantini E.A.C., Lizio-Bruno F., 1996. I suoli del comprensorio vitivinicolo di Montepulciano. Le loro caratteristiche, gli ambienti, i caratteri funzionali per la produzione di Vino Nobile di Montepulciano. Vino Nobile di Montepulciano: zonazione e valorizzazione delle risorse naturali del territorio. (F. Campostrini ed E. Costantini ed.). Regione Toscana, Firenze, pp. 47-74.
· Costantini E.A.C., Lulli., Catone I., Pinzauti S., 1985. Serie e fasi di suolo sui depositi pliocenici marini territorio di San Gimignano (Siena). Indagine preliminare per la definizione delle aree idonee alla produzione della Vernaccia D.O.C.G.. Ann. Ist. Sper. Studio e Difesa Suolo, XVI: 247-288.
· Costantini E.A.C., Lulli L., Mirabella A., 1991. First experiences to individuate soils suitable for the production of high quality Vernaccia of San Gimignano. Atti del simposio internazionale: La gestion territorio viticolo sulla base delle zone pedoclimatiche e del catasto. S.Maria della Versa (PV) 29-30 giugno 1987, pp. 125-135.
· Costantini E.A.C., Lulli L., Pinzauti S., Cherubini P., Simoncini S., 1990. Indagine sui caratteri funzionali del su olo che agiscono sulla qualità del vino. Atti del X° incontro su: contributi ed influenza della chimica nella produzione, conservazione e commercializzazione del vino. Ist. Chimica org. Univer. Siena, pp. 27
· Falcetti M., De Biasi C., Aldrighetti C., Costantini E.A.C., Pinzauti S., 1998. Atlante viticolo. Il contributo del progetto zonazione alla conoscenza, gestione e valorizzazione del vigneto della Cantina La Vis. La Vis, Lavis, Trento, pp. 214.
· Falcetti M., De Biasi C., Aldrighetti C., Costantini E.A.C., Pinzauti S., Bezzi F., 1999. Progetto di zonazione delle valli di Cembra e dell'Adige. Analisi del comportamento delle varietà Pinot nero in ambiente subalpino. Atti del 2° convegno internazionale “zonazione viticola”. Ass. Naz. Città del Vino Siena, pp. 509-515.
· Gardin L., Napoli R., Costantini E.A.C. 1996. Architettura di un database relazionale per un sistema informativo pedologico. Bollettino SISS, 8: 165-182.
· Gardin L., Sulli L., Napoli R., Gregori E., Costantini E.A.C., 1998. Manuale per il rilevamento del suolo. Ist. Sper. Studio e Difesa Suolo, Firenze, pp.83.
· Gregori E., Costantini E.A.C., Gardin L., Napoli R., Sulli L., 1999. Uso integrato di gis, database e sistemi esperti per la gestione del territorio e la conservazione del suolo. Atti del convegno: la difesa dalle alluvioni (M.Falciai e F.Preti ed.). Univ. di Firenze, pp. 453-472.
· Grillotti Di Giacomo M., 1992. Una geografia per l'agricoltura. Vol. primo. Reda, Roma, pp. 367
· Hudson B.D., 1992. The Soil Survey as Paradigm-based Science. Soil Sc. Am. J., 56: 836-841.
· Lebon E., Dumas V., Morlat R., 1997. Influence des facteurs natureles du terroir sur la maturation du raisin en Alsace. 1er colloque international “les terroirs viticoles” Angers, France, INRA, pp. 359-366.
· Lulli L., Costantini E.A.C., Mirabella A., Gigliotti A., Bucelli P., 1989. Influenza del suolo sulla qualità della Vernaccia di San Gimignano. VigneVini, 1/2: 53-62.
· Lulli L., Costantini E.A.C., 1992. L'uso del telerilevamento nello studio dei suoli: possibilità e limiti. L'immagine nel rilievo (C.Cundari ed.) Cangemi, Roma, pp. 388-389.
· Lulli L., Lorenzoni P., Arretini A., 1980. Esempi di cartografia tematica e di cartografia derivata (sezione Lucignano - Foglio Firenze) - La carta dei suoli,la loro capacità d'uso, l'attitudine dei suoli all'olivo e al giovese. C.N.R., P.F. Conservazione del suolo, Firenze, pp. 127.
· Napoli R., Costantini E.A.C., Gardin L., in press. Metodologia di costruzione di un sistema informativo pedologico per le valutazioni agro-ambientali a scala di dettaglio e semi-dettaglio. Agricoltura Ricerca.
· Toscana. Dip. agricoltura e foreste, 1992. I sistemi territoriali della Comunità montana Alto Mugello Mugello Val di Sieve: studio per una caratterizzazione fisica dell'ambiente mugellano (Progetto sistemi territoriali). Giunta Regionale Toscana, Firenze, pp.198.
· USDA, 1993. Soil Survey Manual. Handbook 18, USDA, Washington D.C., pp. 438.

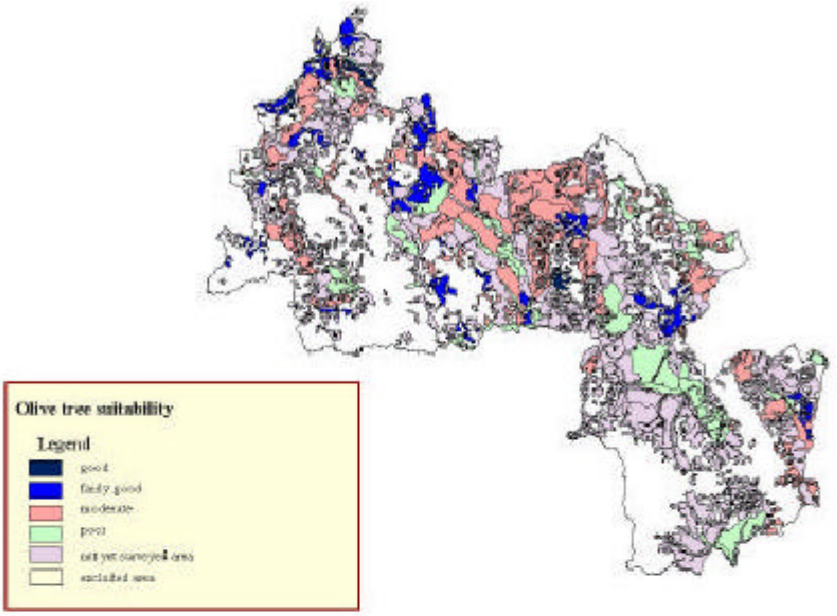
· Van Leeuwen C., Seguin G., 1997. Incidence de la nature du sol et du cépage sur la maturation du raisin, Saint Emilion, en 1995. 1er colloque international “les terroirs viticoles” Angers, France, INRA, pp. 154
157.

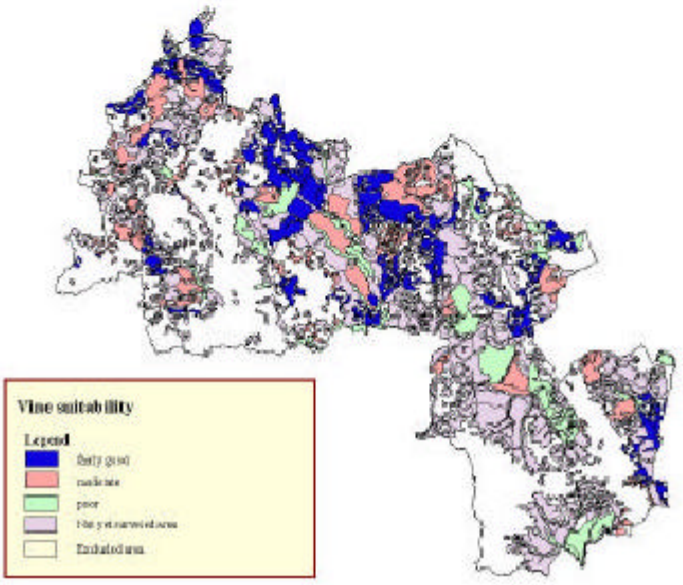





Poggibonsi
Radda in Chianti
San Gimignano
Monteriggioni
Siena
Sovicille
Radicondoli
Chiusdino
Sinalunga
Montepulciano
Montalcino
Radicofani
Castiglione d'Orcia
Experimental farm
Towns


Land System Units of Siena province
Limit of polygon


Olive tree suitability
Legend
good
fairly good
moderate
poor
still yet surveyed area
excluded area


Vine suitability
Legend
fairly good
moderate
poor
Not yet surveyed area
Excluded area