Interaction of Soil Information System and Remote Sensing for Identification of Land Use in Relevant Soil Mapping Units*

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Abstract

For practical purposes, ancillary information is often required from users to pedological cartography. In fact, once the relevant soil mapping units of interest are defined and selected, the user wants to know either the prevalent land use/land cover classes or their association within each soil mapping unit. These data are frequently used for environmental monitoring programs and for assessment and evaluation of the agronomical productivity of soils. Currently the answer to this need coincides with a consistently time consuming, and it requires the selection of several point of observations correspondent to each mapping unit, and eventually to the pedological delineation, and the surveys and mapping of the in field ground truth of the land use/land cover.

ERSAL and CNR have recently developed separately two geographical information systems for soil applications in Italy and the assessment of the impact of the agrotechnologies on the environment: the Lombardia Soils Information System (LOSIS), and the Integrated Geographical Information System (IGIS). In the LOSIS information concerning the relevant soil mapping units derived from in field observations and surveys is collected and mapped, while IGIS is based essentially on georeferred satellite remote sensing images, their supervised classification, cartographic and thematic maps, and some in field surveys. In this paper the fusion of the two systems is described with the production of synthetic final maps at the scale of 1:250,000 compatible with the period and season of observation, with informative

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tables, resuming the main soil mapping unit associated to the prevalent land use/land cover class. A further interaction between the developed systems with a more general GIS developed by the Lombardia Region is proposed to create an easier information access and support to the users.

Résumé

Interaction entre un système d'information pédologique et la télédétection pour l'identification de l'utilisation des terres à l'intérieur des unités cartographiques des sols.

Dans le domaine applicatif de la pédologie, une information complémentaire, souvent liée aux cartes mêmes, est demandée de la part des utilisateurs. En effet, lorsque les unités cartographiques des sols sont sélectionnées et définies, l'utilisateur final désire connaître soit les classes de couverture d'utilisation prévalente des terres soit leur association dans chaque unité cartographique du sol. Ces données sont fréquemment utilisées dans les programmes de suivi du milieu et des ressources naturelles, et pour l'évaluation de la productivité agronomique des sols. Le plus souvent, la réponse à cette nécessité exige des opérations longues qui requièrent la sélection de points d'observation correspondants à chaque unité cartographique, et éventuellement à délinéation pédologique, et enquêtes sur le terrain pour établir l'utilisation effective du sol.

Récemment, l'ERSAL de la Région Lombardie et le CNR d'Italie ont développé deux systèmes d'information pour les applications dans le champ de la pédologie, aux fins de l'évaluation de l'impact des agrotechnologies sur l'environnement; ce sont respectivement, le Système d'Information des Sols de la Lombardie (LOSIS) et le Système d'Informations Géographiques Intégré (IGIS). Plus précisément, le LOSIS contient des informations concernant les unités cartographiques clés des sols, Provenant des observations recueillies sur le terrain, tandis que l'IGIS est basé essentiellement sur les images géo-rectifiées acquises par télédétection, complétées par des classifications supervisées et des données de type cartographique et de vérité terrain. Dans cette étude est présentée la fusion des deux systèmes avec un cas applicatif fournissant des cartes synthétiques finales à l'échelle 1/250 000, en relation à la période d'observation, avec des tables numériques résumant les unités cartographiques du sol associées à la classification de l'utilisation ou couverture prévalante de terres. Une interaction ultérieure entre ces systèmes et un GIS plus général développé par la Région Lombardie est proposée au fin de permettre un accès plus facile de la part de l'utilisateur final.

1. Introduction

Territorial information is often heterogeneous or not sufficient for a correct and exhaustive analysis. In this case the soil-landscape map and the land use map upgraded and upgradable are of basic importance. In general, land use maps at regional scale are still produced with statistical supervised methods with legends chosen time to time in function of the particular use or necessity. This generates several heterogeneous land use maps, often non comparable each other. The future strategies run in the direction of an homogeneous land use map of the whole Europe following the method and the nomenclature defined by the CORINE land cover project. The scale of realisation is 1:100,000. These maps in Italy will be completed before the end of the 1995. At the moment in Lombardia the land use map is not available yet. For the exploitation of this study a simplified land use map according to the first level of the CORINE nomenclature is produced using as input data the Landsat TM scenes.

In Italy the soil-landscape map is still in a first step of actuation. Several Regions do not have at all soil maps. Lombardia Region is one of the most advanced among them and surveys in several provinces are almost completed. Data are digitised, georefered and output available in ARC/INFO format. Maps in scale 1:100,000 are since few years, and in some cases months, available. Maps in scale 1:25,000 and 1:50,000 will available in the medium future. The areas of survey concern with altitude below the 350 m above the sea level.

2. Objective

The high demand of territorial information concerning the relationship between Land Unit and Land Use are at the base of the present study. Once the relevant soil mapping units of interest are defined and selected, the user wants to know either the prevalent land use/land cover classes or their association within each soil mapping unit. In this paper a practical application is developed, for a small sample area, to evaluate the level of information that can be extracted from satellite imagery and compared with the soil-landscape sub-systems classes.

The results derive from the interaction of the two information systems IGIS and LOSIS. Therefore, a considerable effort is to be profuse to link in an opportune way the two databases. The final output is a synthetic map at a demonstrative scale of 1:250,000, with associated informative tables, that can be easily consulted by the users. A visual interpretation of the final land use map must complete the description of the two maps to associate locally the classes.

3. Study area

North Italy includes a large alluvial plain, called Padania or Po Valley, bordered north-west by the Alps, south by the Apennines. The plain has a substrate of coarse sediments, mainly quaternary, that, from a geomorphological point of view, is characterised by the presence of typical features of the fluvial system (Po river).

The study area is located in the middle of the plain, south of the Garda Lake and north of the Po river into the large plain that the river forms. The area limits correspond to the administrative boundary of the province of Mantova in the Lombardia Region. The main interest is focused on the zone between the Chiese (west) and Mincio (east) rivers, that flow in direction north-south. Mincio is tributary of the Po river and is the effluent of the Garda lake. Chiese is an influent of the Oglio river, tributary of the Po. The province of Mantova has a territorial surface 2,340 km².

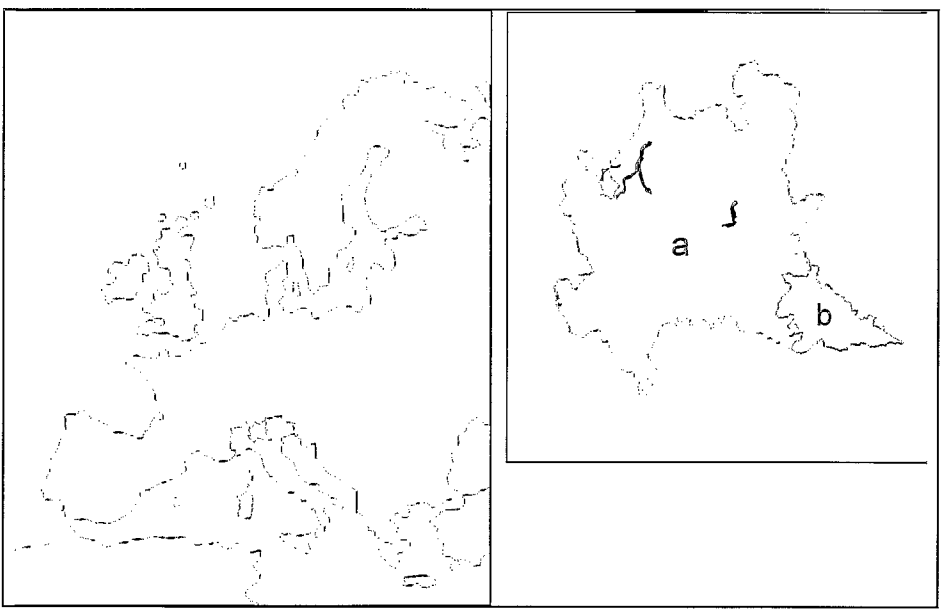

Figure 1. The study area: a - Lombardia Region, b - province of Mantova.

4. Materials and methods

The Geographical Information Systems

Two information systems were developed separately by the CNR-IRRS-Remote Sensing Unit and ERSAL, Lombardia Region, respectively the Integrate Geographical Information Systems (IGIS) and the Soil Information System (LOSIS). The IGIS is based on informational thematic layers digitised from traditional cartographic maps at different detail in scale from 1:1,000,000 up to 1:100,000, and satellite imagery and systems as NOAA-AVHRR, Landsat-TM and SPOT-P, respectively for global, regional and local application. The main application at regional-local scale is the evaluation of the impact of agrotechnologies on the environment.

In the LOSIS the information concerning the relevant soil mapping units is collected and mapped from in field observations and surveys. The cartographic representation of the soil unit is at semy detail level on scale 1:25,000.

Satellite land cover map and soil-landscape map are only in part comparable due to the large differences of details of representation of the respective classes. The soil-landscape map must be simplified and the only relevant soil mapping unit can be used to compare with the land use map. With the definitive realisation of the CORINE land cover map the information will be available at more detailed level.

The most important aspect of the application is the complete compatibility of the two systems that can use indifferently ARC/INFO, AutoCAD, ArcCAD for map digitisation, and geographical coordinate transformation, UTM, Gauss-Boaga, or other systems for geometrical correction and maps-images registration. Furthermore, the digital image processing systems available, IVAS-I²S on Microwax, PCI for Sun station and Ilwis PC compatible, are fully compatible and interchangeable.

Satellite imagery

Three Landsat Thematic Mapper images were used to perform the land use classification of the province of Mantova. The frame is the 192-29, and the chosen periods are 11 June, 27 July and 14 August 1988. A narrow stripe, located north-west of the province, is not included in the Landsat frame and is masked in the processed images. The 87.4% of the province is covered by the Landsat scene, corresponding to 2,044 km².

Other two images were available for the periods February and September 1992, but were not used for this approach yet. In a future development a multi-annual comparison is scheduled to assess the fast evolution of the agriculture into the considered area.

Table 1. Comparison of Land Use in 1988 in the Mantova province between the official statistical data (ISTAT) and Landsat TM classification results. Data are refereed to the surface of the province covered by the Landsat TM scene (N.D.=.No Data).

Land use classes	Source ISTAT (km^2)	Landsat TM (km^2)
Artificial surfaces	260.4	153.8
Agricultural areas	1709.4	1611.4
Forests & Semi-natural areas	83.6	211.8
Water bodies (included Wetlands)	N.D.	76.4
Landsat coverage	2053.4	2053.4
Whole province	2338.8	-

The Soil-Landscape map

The soil-landscape, or soilscape, is identified by several geomorphological Systems defined in the ERSAL (Regional Authority of the Lombardia for the Agricultural Development) catalogue. The main Systems here discussed are:

M System: Morainic Amphitheatre,

L System: Main Level of the Plain, and

V System: Alluvial valleys.

These three groups are separable in soil-landscape sub-systems that represent the minimum parcel chosen for the comparison with the land use classification results.

The sub-systems, differentiated in function of environmental parameters, age of the materials and geographical position, can be summarised as following:

Sub-system MR: includes upper Pleistocene moraines, usually correlated with Wurmian age; they are located in the Northern part of the province and organized drawing a sub-circular pattern. Parent material is very heterogeneous, showing a wide range in texture, mineralogical composition, lime content. They are still at the first step of weathering, and the typical diagnostic horizon is "cambic" (mainly Inceptisols).

Sub-system LG: this class identifies upper Pleistocene surfaces located in the Northern part of the plain. This landform is located between the morainic area, or the foothills, and the loamy part of the L system; the parent material is usually stony or very stony, well graded, typical of glacio-fluvial deposition, calcareous or very calcareous. The soil diagnostic horizon resulting from the soil forming processes is "argillic" (mainly Alfisols).

Sub-system LQ: the class identifies the part of the L system reworked after the formation in the upper Pleistocene; reworking is made by the groundwater coming from stony area in the North, and surfacing at the border LG sub-system and the loamy part of the L System. The area was frequently flooded during the past centuries and reclaimed in the last two

hundred years. Soils are affected by fluctuating water table and "endoaquic conditions" are the most important diagnostic distinctive features (mainly Aquepts and Aquolls).

Sub-system LF: includes, in the South, the loamy part of the main level of the plain; usually well drained, somewhat excessively drained, the soils occurring in this landform show a typical diagnostic "argillic" horizon (mainly Alfisols, loamy or silty families).

Sub-system VT: alluvial terraces of the Oglio and Mincio rivers; surfaces of very late Pleistocene and lower Holocene; the parent material is very heterogeneous, and depends on the deposition and the petrography of the fluvial basin. In the upper terraces the "argillic" is still the most important diagnostic horizon (Alfisols) while in the lower ones no more than a "cambic" horizon occur (Inceptisols).

Sub-system VA: floodplain formed by the Po river and its tributaries Oglio and Mincio; in this sub-system only Holocene surfaces occur, but the parent material is still very heterogeneous following the energy of deposition and the lime content; the drainage is correlated to the permeability and the water table. The formation of a diagnostic horizon is only at the first step: a "cambic" horizon may occur on older overbanks while soils with vertic properties may occur in the backwamps (Entisols; Inceptisols Fluventic sub-groups; Vertisols).

The soil-landscape map of the province has been completed at the end of 1994.

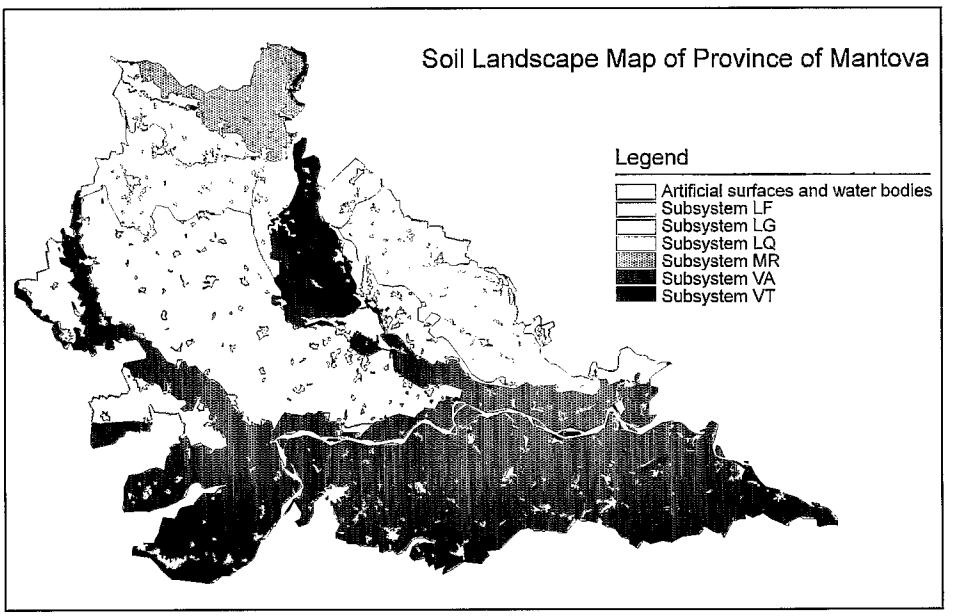

Figure 2. Soil landscape map of the province of Mantova: identification of the soil sub-systems.

Land Use classification

In the near future we schedule to overlay the available soil-landscape maps of the Lombardia Region with the CORINE Land Cover map. In fact, this map is in phase of realisation in scale 1:100,000 following the technical guide of the European Commission. The nomenclature of the map is organised on three level of detail and could add more information at schematic map proposed in this paper. The legend used for the classification of the Landsat TM images was defined following the first level of the CORINE nomenclature (Table 2).

Table 2. Land use classes defined for the Landsat TM of June, July and August 1988 classification as derived from the 1st and 2nd level of the CORINE nomenclature.

LAND USE CLASSES
1. *Artificial Surfaces* (Urban and Industrial areas).
2. *Agricultural Areas.*
2.1.a Arable lands (Bare Arable lands).
2.1.b Arable lands (Vegetated Arable lands in August 1988). 2.2 Permanent crops, 2.3 Pastures, and 2.4 Heterogeneous agricultural areas.
3. *Forest and semi-natural areas*
3.1 Forests, and 3.2 Shrub.
3.3 Open space with little or no vegetation (sand plain).
4. *Wetlands* (flooded natural herbaceous vegetation).
5. *Water bodies.*

Within the class Agricultural Area, Vegetated Arable Lands were separated from the bare arable land in that season. This second level class corresponds, in part, to the autumn-winter crops, as wheat, largely cultivated in the area. Forest and semi-natural areas are distinguished in Forests including Shrub, and Open space with little or no Vegetation that represents mainly the belts, along the Po river and other waterbodies, constituted by sandy material.

5. Discussion and conclusions

The fusion of the two systems has been obtained with the production of synthetic final maps at the scale of 1:250,000 compatible with the period and season of observation, in our case the summer 1988. The aim in the near future is to compare the two maps at a scale of 1:100,000, conserving the high information content of the soil-landscape map and using the CORINE land cover map, produced by default at scale 1:100,000. The table 3 resumes the main soil mapping unit associated to the prevalent land use/land cover class without describe how the land use classes are locally distributed within each soil unit.

Table 3. Association of land use results, from MLL Landsat-TM classification, and Soil subsystem as derived from the LOSIS for the Mantova province in August 1988.

LAND USE CLASSES	MR		LG		LQ		LF		VT		VA	
	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%
Artificial Surfaces	5.5	6.9	6.1	6.7	25.6	9.4	28.9	5.9	15.3	14.8	72.4	7.1
Agricultural Areas												
-Bare Arable Lands	27.3	34.2	33.8	37.4	56.1	20.6	153.7	31.2	36.0	34.9	547.0	53.8
-Vegetated A.L. and Pastures	37.3	46.8	43.8	48.5	167.1	61.5	256.0	52.1	38.9	37.7	214.4	21.1
Forest & semi-nat. areas												
-Forests	8.9	11.2	5.3	5.8	22.0	8.1	29.1	5.9	8.7	8.4	120.0	11.8
-Sand plain	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.5	0.0	0.0	15.2	1.5
Wetlands	0.6	0.7	1.2	1.3	0.6	0.2	3.0	0.6	0.6	0.6	1.2	0.1
Water bodies	0.0	0.0	0.0	0.0	0.0	0.0	18.4	3.7	3.6	3.5	47.2	4.6
Total Surface	79.6	100	90.3	100	271.3	100	491.7	100	103.1	100	1017.4	100

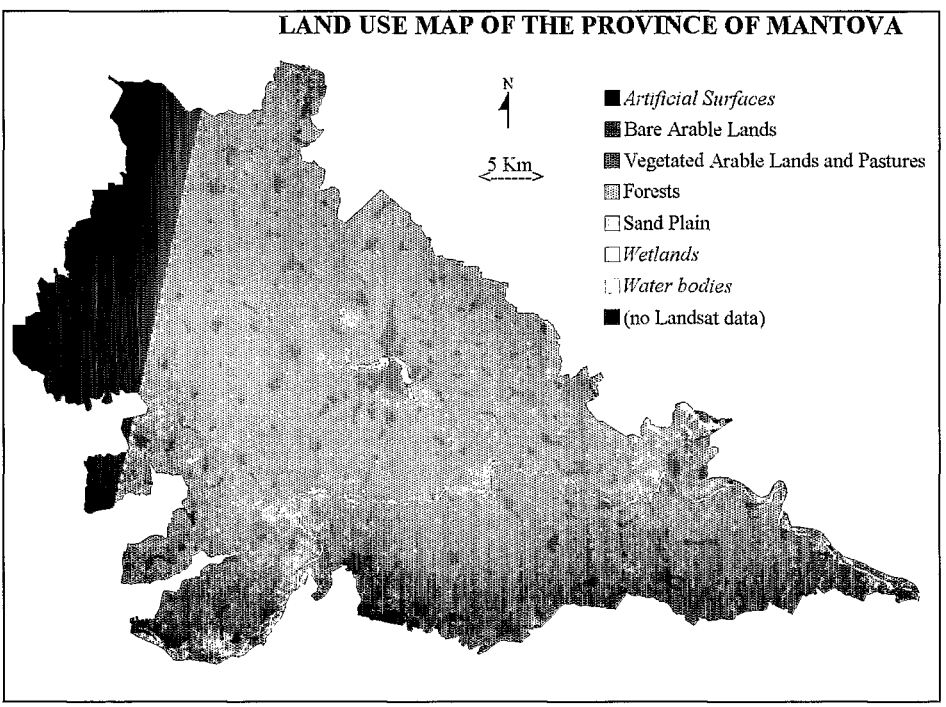

Figure 3. Land use map of the province of Mantova derived from Landsat TM imagery MLL classification.

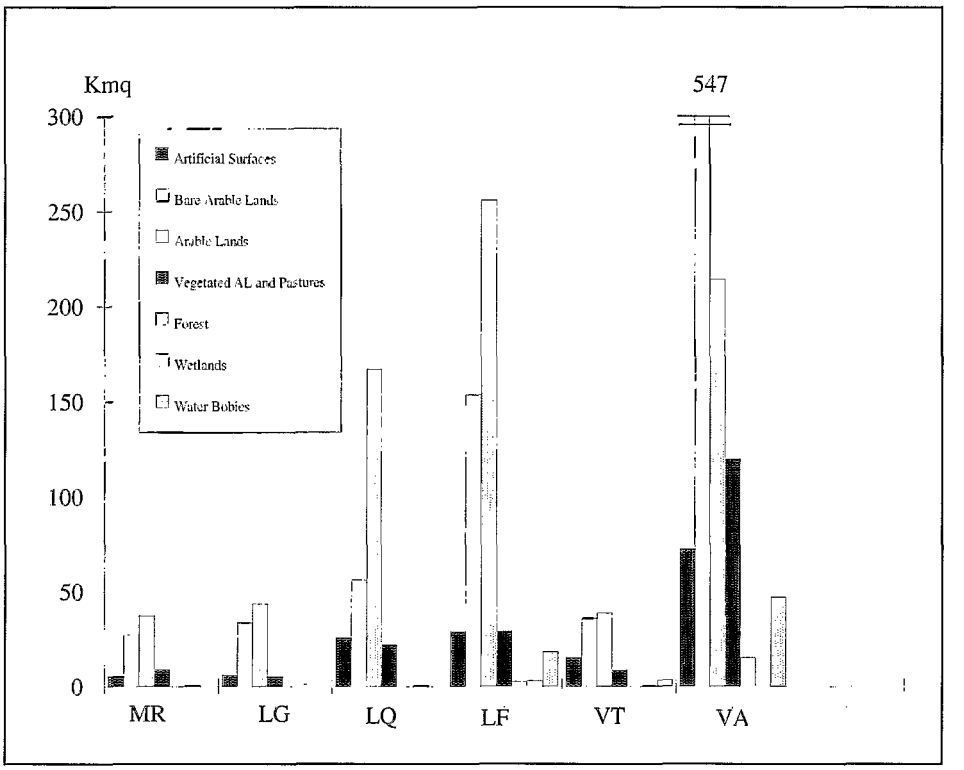

Figure 4. Graphical representation of the data in table 3.

A visual interpretation of the filtered land use map has been completed to define the areal distribution of land use classes within each soil sub-system. A brief description is reported:

Sub-system MR: The smallest sub-system in the Province has mainly agricultural vocation as the other soil-landscape classes;

Sub-system LG: Sub-system subdivided in three similar zone, homogeneous among them;

Sub-system LQ: Urban area with higher density in the south. Forests mainly in the south of the sub-system;

Sub-system LF: Sand plain in the southern part; around the city of Mantova there are two small lakes characterised by the presence of flooded vegetation (Lotus flowers) classified as Wetlands;

Sub-system VT: Northern of Mantova presence of a forest area;

Sub-system VA: The largest sub-system that cover about the 50% of the province of Mantova. The Po river flows in direction west-east cutting the sub-system into two parts. Forests are frequent along the Po river and west. North of the Po river there is a large presence of Bare Arable Lands. Sand Plain class is generally present along the Po river course.

If not mentioned, land use classes are considered homogeneously spread out in the sub-system considered.

The effective final product of this application is the interaction between the two Geographical Information Systems IGIS and LOSIS with an easy information access and support to the users.

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