A portable data acquisition system for field inspections.

On the spot checks of land parcel areas and characteristics: some aspects of current practices and the introduction of a simple and reliable hardware and software set up

by

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Abstract
The preface illustrates the role of field inspectors in Italy, by considering developments occurred in the last 15 years and introducing the need for a portable system to acquire geographic data on the field. Chapter 2 deals with current procedures and shows that the quality of data coming from field inspections can improve significantly by investing into technology and training of inspectors. Field inspectors produce sensible data that are used by IACS; their experience should be considered valuable when designing methodologies, since the perceived efficiency and equity of the allocation of subsidies is also a function of their work.

Chapter 3 summarizes the results of several tests conducted at different locations in Italy about the exclusive use of GPS for land parcel area measurement. It is shown that the precision and accuracy are not adequate for on the spot checks of areas according to current regulation. We would rather use a mixed methodology that includes national LPIS, official data about areas and boundaries, photo imagery, and better training of field inspectors together with the use of GPS devices.

Chapter 4 describes the technical specifications of the portable system, whose test field results are reported in Chapter 5. The set-up of a tablet PC coupled with a GIS software can substitute paper work, speed up field inspections and, assuming a seamless integration with IACS data base (not yet tested), greatly reduce the probability of errors.

This is not a general solution to all open issues about the efficiency of IACS and we did not implement it as a well packaged system for commercial purpose: it is rather a part of an open proposition for a new methodology, which seems compatible with the current know-how and practices.

1 Preface

A short history of the job of field inspectors

On the spot checks of land parcel use -notably the field inspection part, but also by remote sensing- has been the job of hundreds of Italian agronomists and technicians for two decades. We have seen the improvements of the CAP, the evolution of regulations, the changes of the procedures: for many years, albeit not civil servants, we acted as public officers in the ultimate interest of the European Union (by the way, some form of association of these inspectors across the continent seems long overdue). We have been the only human faces representing the EU that many farmers had a chance to meet.

At the beginning, we had to deal with computer systems at the end of our job in the field: we simply input collected data into the PC and then filed floppy disks to the following stage. The software changed every year, its behavior was sometimes erratic, but the human interface coped quite well. Then, the use of the software became more and more pervasive, upgrading versions were countless, the fact that field inspectors had to learn every day one or two tricks to keep on working was given for granted: there was no time for training (see [10], 4.3.2). With the development of the WWW centralization took the stage again: the first year was dramatic; those web pages were very slow to retrieve, the servers were often down, the management of secure access a nightmare. Moreover, due to the use of standard modems over analogical lines (ADSL was still to come) the cost for the user was quite high.

Things improved a lot after that, but it is still useful to make it clear: the main concern of field inspectors is the information system: we do not worry much about the weather, the complexity of procedures, the available time or the gravel roads; we ask ourselves if the next software upgrade will still miss a crucial features, if the Internet connection will be fast and stable; if all forms have been filled and when we will get rid of all the paper work, which has constantly grown over the years. IT has not brought real benefits to field inspections. This must change: the general public is aware of land modeling, GIS and aerial photography, Google Earth shows color images with a resolution that is often much better than the black and white aerial pictures we work with. It is not rocket science anymore.

Portable PC's get to the fields

Two years ago, we, a group of agricultural technicians, some of us with a good background in computing and IT, decided to implement a portable system to acquire geographic data on the field. We drew upon our daily experience with GIS for data acquisition: in fact, we have been using it for forest assessment, single farms managements systems, management of public real estate at a regional level. More recently we took advantage of the advancement of hardware and implemented a complete system which is suitable to field inspections under the procedures of the CAP. We are working toward the implementation of a system based on the open source software method; unfortunately, even if already operative, the project was not completed in time to be presented with all is functions.

This paper deals with two main issues:

- field inspectors are ready to play a less marginal role in the implementation of IACS, both at the member state and at the European level; we would like our opinions to be heard, our experience to be useful to those responsible to design procedures and guidelines
- the technology is mature enough to work in the fields with a sw/hw platform that a few years ago was only available for the desktop. Hardware became lighter and yet robust, software is available at reasonable price /effort. We tested it and want to share our experience.

The choice of the hardware and software that we describe here was made without any support from manufacturers, after testing other solutions. We restricted our search to commercially available products and under no circumstances our opinion should be considered an endorsement for the makers we mention here.

Apart from dozens of professionals that contributed to my experiences throughout the years, I owe much of the development of this project to discussions and to the work done by friends belonging to our group: P. Tosi, C. Scarfoglio, G. Colletta, M, Mariotti, M. Vignoli, A. Piccione, P. Di Prospero and D. Mangiapelo. Without their suggestions and their expertise I would not have been able to finish it. However, they do not share any responsibility for errors. Moreover, the content of this paper is solely personal and not to be intended as expressing the view of our respective firms. It suffices to say that they firmly stand behind the research for efficient solutions.

2 Present day procedures

It is not the purpose of this paper to discuss the general framework of land parcel identification systems, the use of GIS and the integrated administrative control system within the CAP or other European policies that, if efficiently applied, should be based on geographic data and their representation.

However, a few words about the general set up in which we use to work seems quite useful to explain our point of view.

The Italian IACS is a part of the SIAN (national agricultural information system) and SIAR's[2],

2 For Regions where payment agencies different fro AGEA are present

whose main key facts are as follows:

- agricultural firms dealt with are almost 2 millions
- the amount of subsidies transferred to agricultural firms is larger than 6 billions of euro per year
- more than 3000 agricultural assistance centers, located in every region, are linked to the system over the Internet
- all data about the national territory are located and archived on inter operative data base managed by the national and regional paying agencies. They are organized in three levels:
  - ✗ **orthoimagery**, more than 28.000 files that cover Italy 3 times from 1996 and 2003
  - ✗ **cartography**, more than 320.000 cadastral maps, 70 millions of parcels, maps of the IGM 1:25.000, land digital model
  - ✗ **characterizations** of points and areas (attributes), deriving from photo interpretation, field inspections, or declaration by on line users: 4,5 millions of parcels with more 220 millions of olive trees, 650.000 ha with more than 4 millions vineyards; forests, risk of fires, climate profiles etc.

As field inspectors we scarcely have a word on the technical definition of the information technology employed in supporting this complex system. The SIAN has many sources of inputs: with regards to the activities of controlling the demand for subsidies from the CAP, there are mainly three of them.

- Datas coming from the farmers themselves; in Italy each demand is made of a list of parcels identified by their cadastral attributes (Province, municipality, number of map sheet, number of parcel). Information about the cultivated area and the cultivated culture are given for each parcel.
- Data coming from control activities based on photo interpretation of up to date images (this set should grow up, but areas with small parcels typically show high levels of false positive and false negative
- Data coming from field inspections (both parcels that could not be interpreted by remote sensing, have to be confirmed as negative and parcels from a completely different sample)

With the implementation of environmental related constrains (the need to check them) due to the introduction of cross compliance and the enlargement of the IACS to the rural development policies, it seems clear that the quota of data coming from field inspections is going to be larger. Moreover, the type of these data is going to be more complex[3] and their quality must be better.

It is just the case to recall an old saying of IT: G.I.G.O., means “garbage in, garbage out” that is, no matter the system, if the input data are wrong, the decisions based over the output are going to be wrong.

The purpose of this paper is to show that the quality of data coming from field inspections can improve significantly by investing into technology and training of inspectors and by updating the procedures. The enhancement of these aspects is a necessary condition to increase the efficiency of the whole system.

Nowadays the work of a field inspector requires different expertise and inputs. First of all he needs to be a technician that understands agricultural systems, that recognizes vegetable and animal species and varieties in each of their development stages, that is willing to study hundreds of pages of technical references containing the procedures each year. He also needs to be able to talk to people, to overcome their distrust, to understand the public role he is playing by showing firmness and courtesy. Then, he needs to drive a car over gravel roads, bypass gates and find his way to a parcel, jumping from a standard 1:200.000 tourist map to a 1:2000 cadastral map (yes, in Italy there is nothing in between; apart from old A0 sheets that show the set of cadastral maps for each

3 The output of a check of an area is a measured scalar number; a similar output for cross compliance is a vector whose elements have to be estimated and judged by a knowledgeable inspector.

municipality). In fact, having practiced orienteering during your teens can help a lot. All this at a quite fast pace, since dead lines are always too close.[4] After arriving into the parcel he basically has to check the culture (even after harvesting) and the area; to sketch the polygon over the map, to shoot a picture, to write down the code for the culture, to fill multiple forms and to start again with another parcel. After that, he gives all his maps and filled forms to technicians that paste the polygons and data into the software.

It is clear that there are many opportunities for errors: with this setting, the only option for quality management is given by ex-post in field audits and little can be done ex-ante. Usually, negative results from audits only mean that the work has to be done again. However, the training of the involved technicians has a major impact on quality: everyone must know perfectly well his task and also have a pretty good idea of the other stages.

3 Some field results with GPS measurements.

The principle and definition of technical tolerances are laid down in [2] chap. 5 and in [5] chap. 4. An earlier recommendation for the use of standalone GPS devices is [11].

We conducted some tests of GPS measurement of land parcels having in mind the methodological aspects of the current regulation. In what follows the usual definitions are assumed; in particular:

- precision is the degree of mutual agreement among a series of individual measurements
- accuracy is the degree of conformity of a measured or calculated quantity to its actual (true) value

In Table 1 you can see the results of our test. We choose 6 polygons at different latitudes in Italy from the province of Salerno to that of Modena. The second column lists the vertexes of the six polygons and the 3 following columns “measures A” show the “true coordinates”.

These values are the average of multiple measures taken with a base station differential GPS, the model Leica SG50; sometimes several hours were needed to stabilize the results.

The column “measures B”, only reporting the decimal second part, lists data that were taken with 3 different hand held GPS devices: two Garmin e-trex and one Magellan eXplorist XL. For each vertex we took 7 measures with each GPS, with a total of 21 measures: the shown value is the average.

The column “mean error” measured in decimal seconds of degrees is simply the difference between the preceding values of coordinates: in a way this gives us the accuracy of the measurement. With regard to precision, it must be said that the standard variation of the set of measures taken with the three hand held devices is quite large, even after eliminating the outliers.

For convenience we computed the corresponding errors in meters, shown in the right end column[5].

It is clear that those results show that neither precision nor accuracy of hand held devices are adequate to the standards given by the current regulation. We were not able to replicate results of [11] chap. 2, where the magnitude of errors is expressed in cm.

The corresponding errors in surface measurements, were as follows: 2,1%, 7,2%, -14,2%, 2,5%, -31,6% and 6,5%.

In other tests we experienced several cases of unavailability of signals from satellites: this typically occurs on the northern slope of mountains, in presence of trees (above all if wet), close to urban areas.

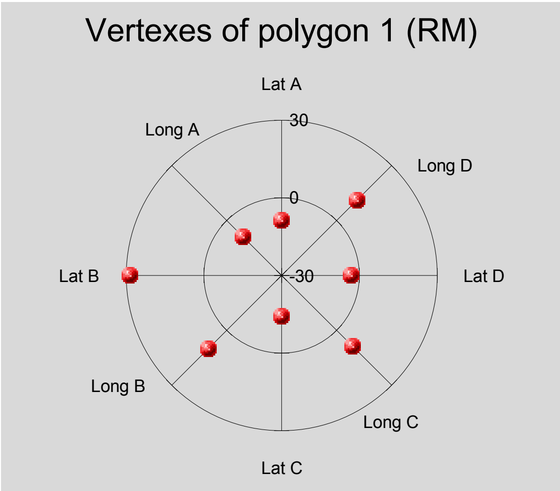
4 Farmers can file their declarations until June/July and this means that sampling can only start very late. A possible solution is to sample firms on the base of their past declarations but this could be tricky: mostly because ex-post declarations could be based on the results of the inspections.

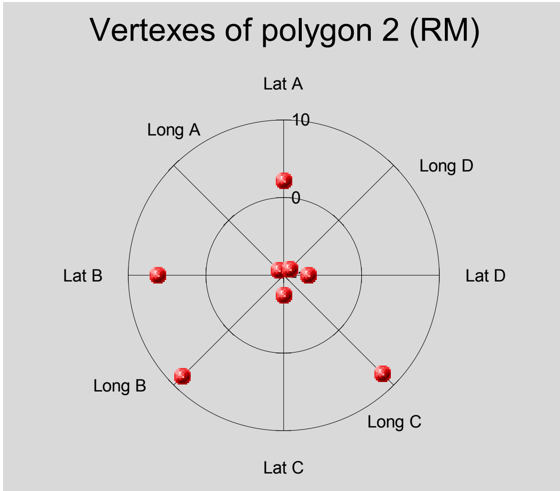
5 Notice that the linear transformation of degrees into meters on the ground is a function of latitude, longitude and elevation

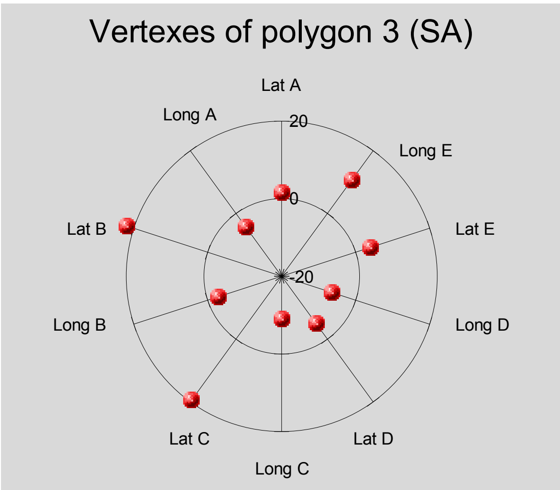
Table 1: 6 examples of hand held GPS accuracy

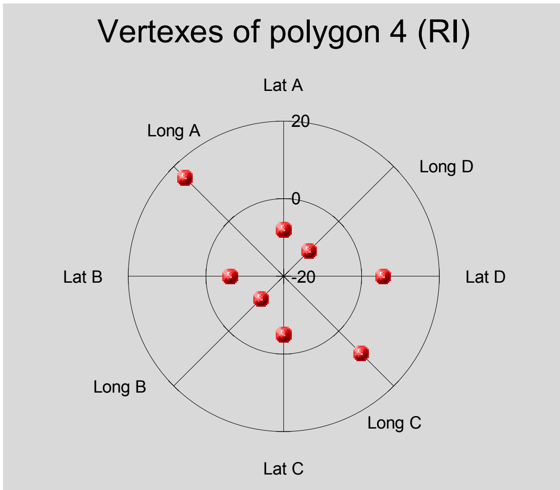
		Measure A			Measures B	Mean error	Mean error
Polygon	Vertex	Degree	Minute	Dec sec	Dec sec	Dec sec	Meters
1 (RM)	A	41	45	55,19	55,47	-0,28	-8,64
		12	17	58,72	59,10	-0,38	-8,88
	B	41	46	1,32	0,39	0,93	28,69
		12	17	54,98	54,55	0,43	10,05
	C	41	46	7,90	8,36	-0,46	-14,19
		12	18	4,90	4,53	0,37	8,65
	D	41	46	1,47	1,57	-0,1	-3,08
		12	18	8,80	8,32	0,48	11,22
2 (RM)	A	41	46	18,73	18,66	0,07	2,16
		12	17	54,08	54,47	-0,39	-9,11
	B	41	46	29,16	28,96	0,2	6,17
		12	18	9,61	9,25	0,36	8,41
	C	41	46	41,92	42,16	-0,24	-7,4
		12	17	53,33	52,99	0,34	7,95
	D	41	46	31,33	31,55	-0,22	-6,79
		12	17	39,05	39,43	-0,38	-8,88
3 (SA)	A	40	36	10,64	10,59	0,05	1,54
		14	56	58,19	58,37	-0,18	-4,27
	B	40	36	14,84	14,13	0,71	21,9
		14	57	2,16	2,28	-0,12	-2,85
	C	40	36	17,46	16,83	0,63	19,43
		14	57	4,32	4,70	-0,38	-9,01
	D	40	36	17,46	17,62	-0,16	-4,93
		14	56	59,58	59,85	-0,27	-6,4
	E	40	36	13,19	13,06	0,13	4,01
		14	56	54,41	53,96	0,45	10,67
4(RI)	A	42	20	52,97	53,23	-0,26	-8,02
		13	8	39,77	39,08	0,69	15,88
	B	42	20	55,59	55,79	-0,2	-6,17
		13	8	37,41	37,92	-0,51	-11,74
	C	42	20	59,39	59,55	-0,16	-4,94
		13	8	41,79	41,44	0,35	8,05
	D	42	20	58,44	58,26	0,18	5,55
		13	8	45,08	45,55	-0,47	-10,82
5 (SP)	A	44	13	39,03	38,72	0,31	9,57
		9	57	40,81	41,43	-0,62	-13,81
	B	44	13	43,22	43,08	0,14	4,32
		9	57	44,17	43,74	0,43	9,58
	C	44	13	44,4	45,3	-0,9	-27,78
		9	57	42,57	42,05	0,52	11,59
	D	44	13	40,13	38,89	1,24	38,27
		9	57	39,02	38,66	0,36	8,02
6 (MO)	A	44	37	14,79	14,36	0,43	13,27
		10	53	3,99	3,46	0,53	11,81
	B	44	37	12,47	12,64	-0,17	-5,25
		10	53	13,66	13,16	0,5	11,14
	C	44	37	21,55	22,06	-0,51	-15,74
		10	53	18,48	17,65	0,83	18,49
	D	44	37	24,49	24,23	0,26	8,02
		10	53	9,07	9,61	-0,54	-12,03

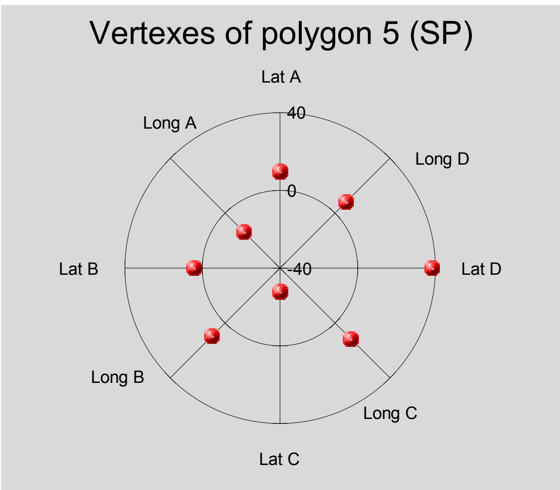
Table 1: Mean errors of coordinates of 6 polygons in meters

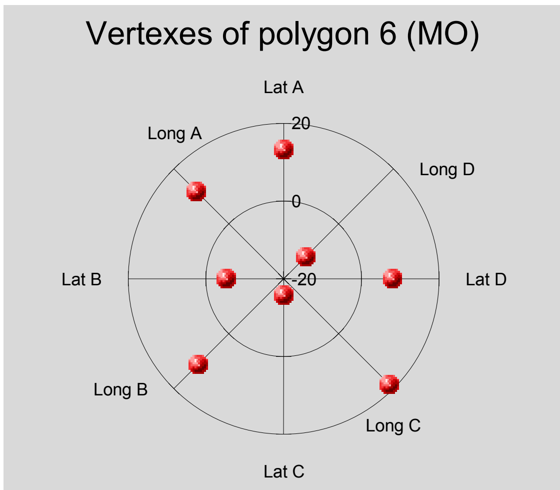












In Table 2 I show the same data of the right wing column of Table 1 arranged for better visualization. Each red point stays on an axis indicating the error of either latitude or longitude: if the error was zero, a point would stay along the inner circle. A position external to the inner circle indicates a positive error, while a position between the center and the inner circle indicates a negative error. The range of magnitude is indicated in meters by numbers on the vertical axis.
These negative results convince us to advocate the use of a mixed methodology, of the type implemented in Italy: the GPS device helps individuating the parcel and positioning into large parcels and the availability of recent aerial photographs into which is possible to locate known fixed points allows for accurate measures of areas. The availability of sketch maps returned by farmers with their application would further enhance the efficiency of this methodology.
The widespread use of more expensive base station differential GPS receivers would force us to rethink our current procedures: apart from the higher cost of the hardware, the productivity in terms of land parcels checked each day diminishes by a factor of 10.

4 Description of the proposed set-up

As I said before, we started the project of transferring our experience with desktop based GIS to portable PC's two years ago. In our search for a solution we had in mind the following set of objectives:

- the device has to be commercially available;
- the cost of ownership should be on a level comparable to high quality portable PC's
- the device has to be stronger than average, reliable and not weight over 2,7 kg
- it need to be able to operate for at least four hours on one battery set
- hardware and software should ensure sufficient precision of graphical input
- the software should facilitate the work of technicians and be able to output data in the needed formats

The Fujitsu-Siemens Stylistic ST5031D we have been using lately is a tablet PC loaded with Windows XP Tablet Edition 2005.
This is one of the latest models of the Fujitsu-Siemens tablet PC line, that was first introduced in 1993. It is a slate tablet, not a convertible, so it lacks the keyboard. All input comes from a pen, which can be used as a pointing device like a mouse, for writing on a virtual keyboard or with the help of handwriting recognition directly on the pressure-sensitive LCD screen. These features are provided by the OS and in our experience they work pretty well, even in the field.
Hardware is quite advanced: CPU Intel Pentium M 753 ULV (ULV stands for Ultra Low Voltage) at 1,2GHz, TDP 3-5 W, 2MB L2 cache, 400 Mhz FSB, 512 MB RAM, Intel 915GM chipset that provides 2 USB 2.0 ports, 10/100/1000 Ethernet, integrated VGA up to 1024x768 internal, 60 GB HD. Other chips provide IRDa, Bluetooth, wireless LAN 802.11a/b/g, modem connections. In addition to that, the tablet provides 1 type I or II PC Card Slot, 1 dedicated SmartCard slot, 1 SD/Sony Memory stick slot, 1 stereo sound output, 1 mic input, 2x IR keyboard port, 1 IEEE 1394 port, external VGA. A serial RS232 port is missing, but can be added with a USB to serial adapter.
This hefty feature set makes this slate easily connected to almost every external device for our field work, but the most important is the 6-7 hours of battery life with the standard 6 cells 5,2 Ah battery or up to 10 hours with the optional 7,8 Ah battery, with LCD lamps turned off, as is usual the case for our purposes. Weight is 1,6 kg. Maximum operating temperature is 35 °C, which can be a limitation for field work at least in Italy in summer. The CPU is passively cooled and in normal operation the tablet does not emit noise nor heat from its vents. The back gets quite warm after several hours operation.
The software of choice is Terranova MapIT, a general purpose GIS data collection program that supports GPS input, ECW and GeoTIFF rasters, shapefile, dxf, Mapinfo and NTF vector formats.

We are currently working with a version of GRASS, in order to evaluate the costs and benefits of using a more adaptable software solution of the open source type. The development of OSS GIS software has accelerated considerably over the past couple of years. There are several interesting projects, but the most striking is UMN MapServer, a web-based solution, that works on standalone systems and over the Internet. It can store vector and attribute data to a spatially enabled SQL server. This is a compelling feature because it can radically solve the data conversion problem that is inherent to proprietary GIS programs. Once a database schema is defined, interoperability between different software implementations is ensured.

5 Field tests

Our tests so far have been positive: the tablet can work for extended hours without glitches. The OS is quite stable and standby/resume is fast and reliable. Handling is easy, but for real deployment a rugged case is mandatory. The tablet is not dust and waterproof: keys, ports and backside vents are not sealed.

We think that a rugged case will make handling easier because the standard case is a bit slippery. In addition, drop protection, albeit partial, is strongly needed for serious work. The rugged case sports a hand strap for carrying and a back strap is also available for holding the tablet. We think that a neck strap, leaving both hands free, would make operation much easier.

We see two limitations that need more testing: high temperature operation and hard disk reliability.

Operation in summer sunlight can raise the tablet temperature well above 35 °C even when air temperature is much lower. Probably with high air temperature and a rugged case around this can be problematic. Since CPU utilization in data collecting operation is very low, we don't fear CPU damages, but other devices might fail (memory, LCD) or malfunction.

Shocks and vibrations in field work and car transportation are a major concern: hard disks are very sensitive because the heads glide over the turning plates and can scratch the disk surface, causing unrecoverable damage to data. While the rugged case can absorb part of the shock, a certain amount of risk remains. Lately, Fujitsu has introduced a new convertible, the T4210, that features a shock sensor utility that addresses this risk. We are looking forward to the introduction of this utility to the slate line. Solid state disks (SSD's) are presently prohibitively expensive. A 4GB SSD costs more than 400 € and a 16GB around 1000 €, but prices are coming down as the first laptops/tablets with SSD are introduced.

We chose the 10.4' outdoor viewable trans reflective screen and in direct sunlight the display is really perfectly viewable: this solution addresses the main problem we had in the past with other portable PC's working outdoors. This LCD type needs the internal illumination bulbs for indoor use only, while outdoors it becomes more visible with high light intensity. Only drawback of this LCD type is color fidelity: while gray scale images are contrasted and pure, yellow and red colors show a magenta slant that is quite noticeable. This has not been a problem for us so far.

We have tested the tablet with a Bluetooth GPS and Terranova MapIT. We tested other programs, but MapIt comes closest to be the best choice.

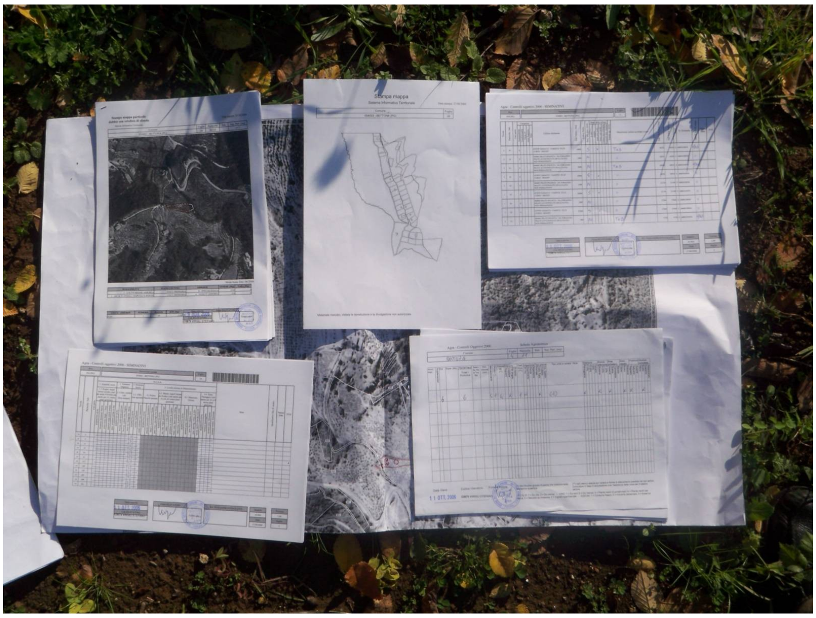
MapIt (by Terranova srl) is a GIS program aimed at data collection in the field, with good support to input (raster and vector georeferencing, form creation, ODBC, etc.) but no analysis functionality. MapIt can show the GPS position over the map, use GPS coordinates for input into a vector layer as lines (arcs) and polygons. It is very light on system resources. It can link vector objects to external files, such as pictures and reports and scribble quick graphic notes for later perusal.

We used a standard GPS with a Nemerix chipset, which is more accurate than the Sirf chipset, according to many sources. In fact, the Sirf chipset is more 'aggressive' in providing a position in difficult conditions (multipath and low signal), which leads to false readings. The Bluetooth radio connection frees the surveyor from the usual mess of cables and can be shared with a car navigation

system. The average rated accuracy is ± 3,5 mt with SBAS, 7 mt without.
Setting up the connection to the GPS through serial BT was quite easy, but the connection is lost when the tablet enters standby. Each time the tablet resumes from standby state, the BT utility must be launched and the connection restarted. This requires 1-2 minutes and we hope to find a solution, such as an automatic or at least a one-click utility that can perform the task This is unavoidable, because the GPS shuts down the BT connection to save battery power. In fact the GPS we used is rated at 8 hours operation with a full battery charge and can be charged from the car lighter. We hope to find a solution to this annoyance, which has not been fully investigated.
Drawing on the tablet is quite easy, though it needs some adaptation from the user's side. First, the LCD panel is about 5 mm away form the screen glass, causing a parallax positioning error of the pen tip if the viewer is positioned at an angle with the screen. This is annoying at first, but it is easy to get accostumed to after some trial and error. Second, to mark the end of a line or to close a polygon, MapIT requires to press the right mouse button, that is emulated on the pen by pressing a tiny button on the pen and double-tapping the screen. This needs to be changed because it is necessary to firmly hold the button while tapping and the gesture is less accurate than a normal single tap.
We have investigated other options, but we think that this tablet, coupled with a rugged case, is the most cost effective solution on the market so far for our purposes. The GPS could be integrated into the case or strung to it (it is too easy to forget the GPS in the car or lose it). Rugged UMPC's are appearing on the market, but the price tag is quite high and screen size is smaller: moreover, nobody announced a trans reflective display so far. The tablet can load ortho images for a whole province in its large disk. This eases data distribution problems: it is a significant advantage over PDA based solutions, that are usually limited in connectivity too.
The MapIT software is functionally complete, but is still designed with the desktop user in mind, equipped with a large screen and accurate mouse. Menu item selection could be enhanced with bigger icons and context adaptive menus, to save precious screen area.
It is also possible to associate an electronic signature to each input data, in such a way that the responsibility and identification of technicians is assured.

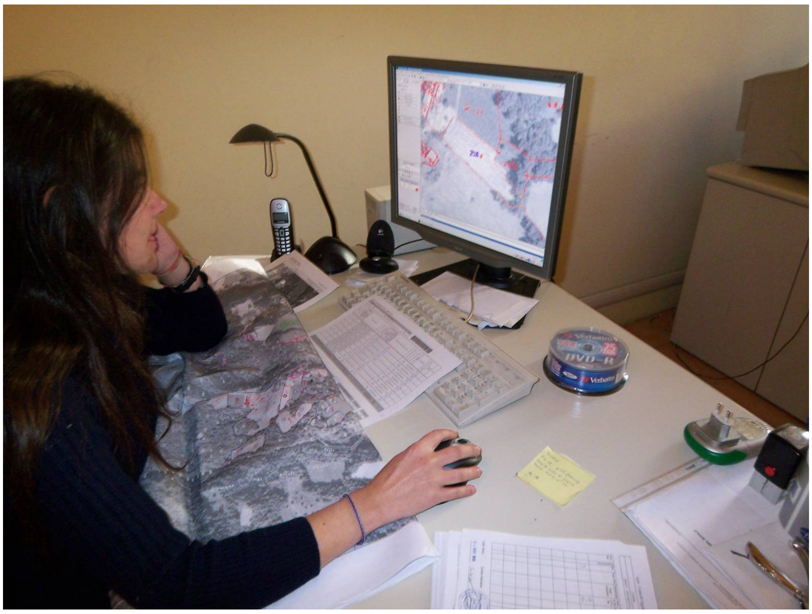
Some pictures follow.

A 1 what GIS DAD can replace



A 2 drawing lines and writing on the map

A 3 pasting input data from the map to the software



B1 components of GIS DAD

B2 working with GIS DAD

6 Conclusions

Field inspectors produce sensible data that are used by IACS; their experience should be considered valuable when designing methodologies, since the perceived efficiency and equity of the allocation of subsidies is also a function of their work.

Our tests show that currently the exclusive use of low cost GPS receivers in order to measure areas it is not adequate. We advocate -without further discussion here- the adoption of a mixed methodology that includes national LPIS, official data about areas and boundaries, photo imagery, and better training of field inspectors together with the use of GPS devices.

The system presented here works fine for the purpose of field inspectors. It is a reliable substitute for paper maps, forms, photographs and color pencils. The integrated GPS helps finding and positioning in parcels but we think that both precision and accuracy fall short of the levels required by the current regulation. The output can easily be input into other systems, even if we foresee a series of problems with reproduction of polygons. However a complete knowledge of the structure of the data base should allow for a solution.

This system is quite compatible with the current procedures and work flows used by field inspectors in Italy: its implementation would only require a reallocation of costs, since saving in other stages (e.g. printing) can suffice to buy the tablets PC's and to finalize the software. Also, an investment into training of human resource will be needed.

Given the complexity of the IACS, we strongly believe that the better solution in the short term would be to run a test on a large scale before the 2007 campaign.

Last but not least, outside of the IACS, the system is a perfect device for gathering any kind of data that require a spatial representation.

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