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Feasibility study on automated geo-referenced data entry of agricultural land use

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1. Introduction

Land use concerns the activities undertaken on the land in order to obtain benefits from it. However, certain land use activities could have undesirable effects (e.g. land degradation). Knowledge of land-use practices is therefore crucial for defining various interventions (e.g. policies, investment strategies, choice of sustainable technologies, etc.) that would lead to desirable modifications in how land is managed in order to better meet societal needs. In particular, land use information is needed by countries in order implement action programs related to the achievement of the Millennium Development Goals 1 and 7 and a range of activities within the framework of various global environmental conventions, such as the United Nations Convention to Combat Desertification (UNCCD) and the United Nations Framework Convention on Climate Change (UNFCC). Despite its importance, very little global to regional land-use information, based on actual observations, currently exists.

The work to be carried out in this study aims to assist AGLL in developing a prototype hand-held, automated, field data entry tool that can easily be adapted to varying data collection needs during land-use surveys, which could be used as a basis for appropriate policy formulation at various scales, and also be a crucial input in the formulation of remedial measures in land degradation assessment studies, such as LADA.

It is understood that to undertake a land use survey, there is first an essential requirement to identify policy needs for implementing such a methodology at an operational level for an entire country. Then, a suitable classification scheme will be defined that will enable the acquisition of the necessary data to fulfil these policy requirements.

It was not possible to include this initial step as part of this study, but the authors were careful to define the main lines of enquiry to ensure that the classification methodology adopted could be easily adapted to accommodate policy needs. Also, although other types of surveys will be reviewed, the prototype data collection system developed as part of this work, is based around a point sample similar to that applied as part of the LUCAS survey in Europe.

A manual describing the steps to be carried out to undertake a field survey based on the selected GPS data collection unit and supplied example data dictionary is available in Appendix A.

2. Classification scheme

2.1. Background

Classification is the process by which features can be allocated to defined categories by matching their attributes to individual category definitions through the use of diagnostic criteria. This produces a simplified representation of reality. Each category in the classification will normally be assigned a name and description, providing the user with the information required to interpret the classification result. The diagnostic criteria used in the classification should be clear, precise, preferably quantitative and objective.

Land classification systems have been developed for many purposes, for example, characterisation of soils, land capability assessment, land suitability assessment, land cover and land use mapping. It is the latter two examples that are pertinent to this report. A common requirement for these types of classification is that they should be scale independent i.e. the categories can be applied to any mapping scale, and source independent i.e. a range of data sources could be used to collect information.

Many attempts have been made to develop land cover and land use classifications. Land cover is the *'observed (bio)physical cover of the earth'* (FAO, 2005).The Land Cover Classification System (LCCS) (FAO, 2005) is formulated on the principle of defining land cover classes by the combination of a set of diagnostic criteria or '*classifiers'*. Class boundaries are determined by either the presence of one or more distinctive criteria or the number of criteria used. This takes the emphasis away from the class name and focuses on the mix of criteria. The advantage of this approach is that it removes much of the subjectivity often associated with a user applying class names and descriptions to land cover classification.

The classification is hierarchical and has two main phases: the *Dichotomous Phase* and the *Modular-Hierarchical Phase*. The initial phase is used to identify eight main land cover classes (FAO, 2005):

- Cultivated and Managed Terrestrial Areas
- Natural and Semi-Natural Terrestrial Vegetation
- Cultivated Aquatic or Regularly Flooded Areas
- Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation
- Artificial Surfaces and Associated Areas
- Bare Areas
- Artificial Water Bodies, Snow and Ice
- Natural Water Bodies, Snow and Ice

Three diagnostic criteria are used to define these classes: presence of vegetation, edaphic condition and artificiality of cover (FAO, 2005).

The Modular-Hierarchical Phase creates more precise land cover classes through combinations of sets of pure land cover classifiers. The set of classifiers used for each main land cover class is different. Information from the classifiers can be augmented by reference to further attributes of the land cover. These could be environmental (e.g. climate, landform, altitude, soils) and/or specific technical attributes (e.g. crop type, soil type, salinity).

Land use refers to '*the human activities which are related to land, making use of its resources and having an impact upon it'* (Young, 1998). It is the classification of land use that forms the main focus of this section of the report. The following subsections propose a demonstration data dictionary that is based upon the '*classifier'* principle outlined above.

The land cover and land use classification methodologies below have been selected on the basis of their potential incorporation into a field data collection device. They meet the requirements set out above and represent much of the current thinking on land cover and land use classification.

2.2. Land Use Classification

2.2.1. Background

As has been stated by several authors (Duhamel, 1998; de Bie, 1996, Young, 1998), no universally accepted land use classification has been developed. Duhamel (1998), in particular, analyses the development of land use classifications and his findings are neatly summarised in Jansen (2005). However, many classifications have been formulated within individual countries to meet local needs. Class names may be the same or similar between different classifications but detailed examination may reveal distinct definitional variation. This feature militates against their use as a 'reference' or international classification that will be acceptable to all.

It is often the case that national classifications fail to classify pure land use classes; mixtures of land cover and land use are found within class names and definitions. To a large extent this has come about because of the methods used to collect the land use data. Many land use surveys have used remotely sensed data because it can be a cost effective means of mapping large areas of land. However, only some degree of land use can be inferred from this data by the use of high resolution data sources such as aerial photography. Even ground survey may not be able to identify some land uses, for example, is a forest being used for timber production? Within the original LUCAS survey methodology implemented within Europe, land cover and land use are treated separately. The adaptation of the LUCAS methodology proposed in this report applies this concept within the demonstration data dictionary.

Land use is more complex in concept than land cover. 'Use' can be viewed from different perspectives. For example, there can be what is often termed a 'functional' use that describes the purpose of the use, or a 'sequential' use that describes the operations that take place at the point of observation (Young, 1998). It is suggested by Young (1998) that both need to be included in a classification intended for a wide range of purposes. The US Land Based Classification Standards (LBCS) adopt this approach and expand the range of use perspectives or 'dimensions' (LBCS, 2006). It is sufficiently flexible that 'dimensions' can be added or dropped according to the purpose of the survey. Within each dimension land use categories can be arranged in a hierarchy. Jansen and Gregorio (2003) and Jansen (2005) also categorise land use on the basis of ‘function’ and ‘activity’ and demonstrate the successful implementation of these concepts in Kenya and Albania, respectively. ‘Classifiers’ can be developed from this concept, adopting the approach used in the LCCS, which can be combined in various ways to characterise land use.

Another concept of importance in land use classification is that of ‘multiple use’, for example, forestry areas may perform a production function as well as provide a recreational use. The LANES (1997) programme defines three factors of multiple use that should be considered: mapping scale of observation, vertical superimposition of uses, and temporal mixtures. In some classifications multiple use is not considered (Remmezwaal, 1989). In other classifications the approach is to record what is considered to be the dominant use (ECE-UN, 1989). This may be explicitly defined or implicitly assumed. An alternative is to use a pro-rata approach (Duhamel, 1998). The standard LUCAS proforma makes provision for the recording of multiple land uses. There should be no calculation of pro-rata. In heterogeneous areas, concepts of physiognomic importance and dominance are used (Eurostat, 2003). The land use classification adopted should reflect this provision within the LUCAS methodology.

2.2.2. Proposed classification approach

The potential number of land use categories that could be applicable at continental, regional or national scale is very large. As has already been identified, it is unlikely that an agreed set of categories and definitions could be formulated that would satisfy all purposes given that government policy is often a major factor driving forward land use classification and this varies from country to country and over time. Because policy is subject to change spatially and temporally it is therefore desirable to implement classification approaches that can adapt to changing policy environments. This is a strength of the *‘classifier’* approach inherent within the LCCS. Data collected using this method can be formulated into standard or user defined land cover classes. The same principle can be applied to land use classification and characterisation.

Jansen and Di Gregorio (2003) have applied this approach to an area in Kenya. Land use was derived from remotely sensed imagery supported by field survey and mapped at 1:200,000 scale. The LCCS was used to determine land cover by interpretation of the imagery and from this classification a set of decision rules were established to define land use classes. These studies support the concept of using *‘classifiers’* for land use classification.

The classification contained within the demonstration data dictionary given below incorporates land use classification (derived from Young (1998)), land use characterisation and the LCCS (FAO, 2005) and adopts the principle of using 'classifiers'.

2.2.3. Demonstration data dictionary

Table 2.1 presents a demonstration data dictionary that can be incorporated within a GPS. The LCCS component of the data dictionary only includes three of the tertiary level dichotomous phases. These are considered to account for the majority of land

cover types found within agricultural areas. The remaining phases at this level from the LCCS classification
can be added to the data dictionary if required.

Table 2.1: Demonstration data dictionary

Site Identification Number (required)	**N/A**				
Survey Time (Automatic)	**N/A**				
Survey Date (Automatic)	**N/A**				
Simplified LU classification					
Conservation		Crop production		Settlement	
Total	**LUCON1**	**Shifting cultivation**	**LUCRP1**	**Residential**	**LUSET1**
Partial	**LUCON2**	**Temporary cultivation**	**LUCRP2**	**Commercial**	**LUSET2**
Collection		**Permanent cropping**	**LUCRP3**	**Industrial**	**LUSET3**
Plant products	**LUCOL1**	**Wetland cultivation**	**LUCRP4**	**Infrastructure**	**LUSET4**
Animal products	**LUCOL2**	**Confined crop production**	**LUCRP5**	Use restricted by security	**LUSET**
Forestry		Fisheries production		Other	**LUOTH**
Management – Natural forests	**LUFOR1**	**Fishing (capture)**	**LUFIS1**		
Forest plantations	**LUFOR2**	**Aqua-culture**	**LUFIS2**		
Livestock production		Recreation	**LUREC**		
Extensive grazing	**LULIV1**	Mineral extraction			
Intensive grazing	**LULIV2**	**Mining**	**LUMIN1**		
Confined livestock production	**LULIV3**	**Quarrying**	**LUMIN2**		

Agricultural LU Characterisation

CROPS

Crop Type (required)

Avocados	**CT_572**	**Grapefruit and Pomelos**	**CT_507**	**Peas, Green**	**CT_417**
Bambara Beans	**CT_203**	**Grapes**	**CT_560**	**Pepper, White/Long/Black**	**CT_687**
Bananas	**CT_486**	**Green Corn (Maize)**	**CT_446**	**Pigeon Peas**	**CT_197**
Beans, Dry	**CT_176**	**Groundnuts in Shell**	**CT_242**	**Pimento, Allspice**	**CT_689**
Beans, Green	**CT_414**	**Kapok Fibre**	**CT_778**	**Pineapples**	**CT_574**
Broad Beans, Dry	**CT_181**	**Kapokseed in Shell**	**CT_311**	**Plantains**	**CT_489**
Broad Beans, Green	**CT_420**	**Karite Nuts (Sheanuts)**	**CT_263**	**Plums**	**CT_536**
Cabbages	**CT_358**	**Kolanuts**	**CT_224**	**Potatoes**	**CT_116**
Canary Seed	**CT_101**	**Lemons and Limes**	**CT_497**	**Pulses nes.**	**CT_211**
Cantaloupes and other Melons	**CT_568**	**Lentils**	**CT_201**	**Pumpkins, Squash, Gourds**	**CT_394**
Carrots	**CT_426**	**Lettuce**	**CT_372**	**Rice, Paddy**	**CT_27**
Cashew Nuts	**CT_217**	**Maize**	**CT_56**	**Roots and Tubers nes**	**CT_149**
Cashewapple	**CT_591**	**Mangoes**	**CT_571**	**Seed Cotton**	**CT_328**
Cassava	**CT_125**	**Melonseed**	**CT_299**	**Sesame Seed**	**CT_289**
Cereals nes.	**CT_108**	**Millet**	**CT_79**	**Sorghum**	**CT_83**
Cherries	**CT_531**	**Mixed Grain**	**CT_103**	**Soybeans**	**CT_236**
Cherries, Sour	**CT_530**	**Mushrooms**	**CT_449**	**Spices nes.**	**CT_723**
Chick-Peas	**CT_191**	**Mustard Seed**	**CT_292**	**Spinach**	**CT_373**
Chillies and Peppers, Green	**CT_401**	**Natural Gums**	**CT_839**	**Stone Fruit nes., Fresh**	**CT_541**
Citrus Fruit nes.	**CT_512**	**Natural Rubber**	**CT_836**	**String Beans**	**CT_423**
Cocoa Beans	**CT_661**	**Nutmeg, Mace, Cardamons**	**CT_702**	**Sugar Cane**	**CT_156**
Coconuts	**CT_249**	**Nuts nes.**	**CT_234**	**Sugar Crops nes.**	**CT_161**
Coffee, Green	**CT_656**	**Oil Palm Fruit**	**CT_254**	**Sweet Potatoes**	**CT_122**
Cow Peas, Dry	**CT_195**	**Oilseeds nes.**	**CT_339**	**Tangerines, Mandarines, Clementines, Satsumas**	**CT_495**
Cucumbers and Gherkins	**CT_397**	**Okra**	**CT_430**	**Taro (Coco Yam)**	**CT_136**
Eggplants	**CT_399**	**Olives**	**CT_260**	**Tea**	**CT_667**
Fibre Crops nes.	**CT_821**	**Onions and Shallots, Green**	**CT_402**	**Tobacco Leaves**	**CT_826**
Flax Fibre and Tow	**CT_773**	**Onions, Dry**	**CT_403**	**Tomatoes**	**CT_388**
Fonio	**CT_94**	**Oranges**	**CT_490**	**Vegetables Fresh nes.**	**CT_463**
Fruit Tropical, Fresh nes.	**CT_603**	**Papayas**	**CT_600**	**Watermelons**	**CT_567**

Garlic	**CT_406**	**Peaches and Nectarines**	**CT_534**	**Yams**	**CT_137**
Ginger	**CT_720**	**Pears**	**CT_521**	**Yautia (Cocoyam)**	**CT_135**
Gooseberries	**CT_549**	**Peas, Dry**	**CT_187**	**Other**	**CT_999**

Agricultural LU Characterisation

CROPS

Crop Systems

Bush fallow (shifting cultivation)	**CS1**
Multiple cropping	**CS2**
Crop rotation	**CS3**
Improved cultivars	**CS4**
Agro-forestry	**CS5**
Controlled environment (greenhouse)	**CS6**

Pest/weeds

Pesticides	**PW1**
Fungicides	**PW2**
weed control	**PW3**
Biological control	**PW4**

Nutrients

Organic fertilizer	**NU1**
Mineral fertiliser	**NU2**
Other soil amendments	**NU3**

Erosion

Tillage	**ER1**
Levelling; contour tillage; terracing	**ER2**
Cover crops	**ER3**
Crop residue incorporation	**ER4**

Power Sources

Water Management (Irrigation)

Rainfed	**WM1**
Non-equipped cultivated wetlands & inland valley bottoms	**WM2**
Non-equipped flood recession cropping	**WM3**
Equipped cultivated wetlands & inland valley bottoms	**WM4**
Equipped flood recession cropping	**WM5**
Full/partial control irrigation (surface, sprinkler, localized)	**WM6**
Spate irrigation	**WM7**
Adequate drainage of excess water	**WM8**
Other	**WM9**

LIVESTOCK

Livestock Types

Asses	**LV_1107**
Beehives	**LV_1181**
Cattle	**LV_866**
Chickens	**LV_1057**
Goats	**LV_1016**
Pigs	**LV_1034**
Poultry Birds	**LV_2029**
Sheep	**LV_976**

Cattle Management

Open grazing	**CM1**
Fenced pastures	**CM2**
Stall-fed	**CM3**
Improved pastures	**CM4**
Significant share of imported breeds	**CM5**
Water resources (adequate access?)	**CM6**
Feed (adequate access?)	**CM7**
Credit (adequate access?)	**CM8**
Extension services (adequate access?)	**CM9**
Veterinary services (adequate access?)	**CM10**
Drugs; vaccinations (adequate access?)	**CM11**

Manual	**PS1**		
Animal	**PS2**		
Mechanized means	**PS3**		

Agricultural LU Characterisation	Code				
FORESTRY					
Timber Exploitation		Season Extracted		Disturbance	
clearing	**TE1**	**Dry season extraction**	**SE1**	**protected area**	**DT1**
selective felling	**TE2**	**Rain season extraction**	**SE2**	**exploitation via mgmt plans**	**DT2**
group felling	**TE3**	Silviculture		**many products without mgmt. plans**	**DT3**
strip felling	**TE4**	**crown thinning, selective cutting**	**SL1**	**high rate of deforestation**	**DT4**
Harvest Technology		**freeing from threatening trees, plants**	**SL2**		
manual	**HT1**	**enrichment**			
chainsaw	**HT2**	**sanitary cuttings**	**SL3**		
mechanized	**HT3**		**SL4**		

Land Cover Classification System	Code
A11 - CULTIVATED & MANAGED LANDS	
I. A. Life Form of the Main Crop	
Trees	
Broadleaved	**A1**
Needleleaved	**A7**
Evergreen	**A8**
Deciduous	**A9**
Shrubs	**A10**
Broadleaved	**A2**
Needleleaved	**A7**
Evergreen	**A8**
Deciduous	**A9**
Herbaceous	**A10**
Graminoids	**A3**
Non-Graminoids	**A4**
Urban Vegetated Area(s)	**A5**
Parks	**A6**
Parkland	**A11**
Lawns	**A12**
B. Spatial Aspect - Size	**A13**
Large-to Medium-Sized Field(s)	
Large-Sized Field(s)	**B1**
Medium-Sized Field(s)	**B3**
Small-Sized Field(s)	**B4**
B. Spatial Aspect - Distribution	**B2**
Continuous	**B5**
Scatterred Clustered	**B6**
Scattered Isolated	**B7**

II. C. Crop Combination	
Single Crop	**C1**
Multiple Crop	**C2**
One Additional Crop	**C3**
Trees	**C5**
Shrubs	**C6**
Herbaceous Terrestrial	**C7**
Herbaceous Aquatic	**C8**
Simultaneous	**C17**
Overlapping	**C18**
Sequential	**C19**
Trees	**C13**
Shrubs	**C14**
Graminoids	**C15**
Non-graminoids	**C16**
Simulltaneous	**C17**
Overlapping	**C18**
Sequential	**C19**
III. D. Cultural Practices - Water Supply	
Rainfed	**D1**
Post-flooding	**D2**
Irrigated	**D3**
Surface Irrigation	**D4**
Sprinkler Irrigation	**D5**
Drip Irrigation	**D6**

D. Cult. Practices - Cult. Time Factor	
Shifting Cultivcation	**D7**
Fallow System	**D8**
Permanent Cultivation	**D9**
S. Crop Type	
Food Crops	**S1**
Cereals (& Pseudocereals)	**S3**
Roots & Tubers	**S4**
Pulses & Vegetables	**S5**
Fruit & Nuts	**S6**
Fodder Crops	**S7**
Beverages & Stimulants	**S8**
Other	**S13**
Non-Food Crops	**S2**
Industrial Crops	**S9**
Wood/Timber	**S10**
Other	**S14**

Land Cover Classification System	Code
A12 – Nat. & Semi-Nat. Terrestrial Veg.	
I. A Life Form of the Main Strata	
Woody	**A1**
Trees	**A3**
Shrubs	**A4**
Herbaceous	**A2**
Forbs	**A5**
Graminoids	**A6**
Lichens/ Mosses	**A7**
Lichens	**A7**
Mosses	**A9**
A. Cover	
Closed **(> 70-60%)**	**A10**
Open **(70-60 - 20-10%)**	**A11**
(70-60 - 40%)	**A12**
(40-20 - 10%)	**A13**
Closed to Open **(100 -15%)**	**A20**
(100-40%)	**A21**
Sparse **(20-10 - 1%)**	**A14**
(<20-10 - 4%)	**A15**
Scattered (4-1%)	**A16**
B. Height	
7-2 m **(for Woody)**	**B1**
>30-3 m **(for Trees)**	**B2**
>14 m	**B5**
14-7 m	**B6**
7-3	**B7**
5-0.3 m	**B3**
5-0.5 m	**B14**
5-2 m	**B8**
2-0.5 m	**B9**
<0.5 m	**B10**

3-0.03 m	**B4**
3-0.3 m	**B15**
3-0.8 m	**B11**
0.8-0.3 m	**B12**
0.3-0.03 m	**B13**
C. Spatial Distribution/Macropattern	
Continuous	**C1**
Fragmented	**C2**
Striped	**C4**
Cellular	**C5**
Parklike Patches	**C3**
II. D. Leaf Type	
Broadleaved	**D1**
Needleleaved	**D2**
Aphyllous	**D3**
E. Leaf phenology	
Evergreen	**E1**
Semi-Evergreen	**E4**
Deciduous	**E2**
Semi-Deciduous	**E4**
Mixed	**E3**
Mixed (for Forbs/Graminoids)	**E5**
Annual	**E6**
Perennial	**E7**
III. F. Stratification - Second Layer	
Second Layer Absent	**F1**
Second Layer Present	**F2**
Woody	**F3**
Trees	**F4**
Shrubs	**F5**
Herbaceous	**F4**

G. Cover - Second Layer	
Closed To Open	**F7**
Closed (> 70-60%)	**F8**
Open (70-60 - 20-10%)	**F9**
Sparse (20-10 - 1%)	**F10**
H. Height - Second Layer	
7-2 m **(for Woody)**	**G1**
>30-3 m	**G2**
>14 m	**G5**
14-7 m	**G6**
7-3 m	**G7**
5 - 0.3 m	**G3**
5-2 m	**G8**
2-0.5 m	**G9**
< 0.5 m	**G10**
3 - 0.03 m	**G4**
3-0.3 m	**G11**
0.3-0.03 m	**G12**
F. Stratification - Third Layer	
Third Layer Absent	**F1**
Third Layer Present	**F2**
Woody	**F3**
Trees	**F4**
Shrubs	**F5**
Herbaceous	**F4**
G. Cover - Third Layer	
Closed To Open	**F7**
Closed (> 70-60%)	**F8**
Open (70-60 - 20-10%)	**F9**
Sparse (20-10 - 5%)	**F10**

Land Cover Classification System	Code		Code	
A12 – Nat. & Semi-Nat. Terrestrial Veg.				
H. Height - Third Layer				
7-2 m **(for Woody)**	**G1**	T. FLORISTIC ASPECT		
>30-3 m	**G2**	Single Plant Species	**T1**	
>14 m	**G5**	**Dominant Species**	**T3**	
14-7 m	**G6**	**Most Frequent Species**	**T4**	
7-3 m	**G7**	Groups of Plant Species	**T2**	
5 - 0.3 m	**G3**	**Statistically Derived Groups**	**T5**	
5-2 m	**G8**	**Non-Statistically Derived**	**T6**	
2-0.5 m	**G9**			
< 0.5 m	**G10**			
3 - 0.03 m	**G4**			
3-0.3 m	**G11**			
0.3-0.03 m	**G12**			

Land Cover Classification System	Code		Code
A23 – CULTIVATED AQUATIC AREAS			
I A. Life Form of the Main Crop			
Graminoids	**A1**	S. CROP TYPE	
Non-Graminoids	**A2**	Food Crops	**S1**
Woody	**A3**	**Cereals**	**S3**
B. Spatial Aspect - Size		**Fodder Crops**	**S7**
Large-To Medium-Sized Field(s)	**B1**	**Other**	**S13**
Large-Sized Field(s)	**B3**	Non-Food Crops	**S2**
Medium-Sized Field(s)	**B4**	**Crops for Biological Filtration**	**S11**
S mall-Sized Field(s)	**B2**	**Fibre Crops and Structural Mat.**	**S12**
B. Spatial Distribution		**Other**	**S14**
Continuous	**B5**		
Scattered Clustered	**B6**		
Scattered Isolated	**B7**		
II C. Water Seasonality			
Persistent for Whole Day	**C1**		
With Daily Variations	**C2**		
Waterlogged	**C3**		
III D. Cultural Practices - Fallow period			
Permanent	**D1**		
Relay Intercropping	**D2**		
Sequential	**D3**		

<u>Land Cover Classification System</u>	Code
ENVIRONMENTAL ATTRIBUTES	
L Landform	
Level Land	**L1**
Sloping Land	**L2**
Steep Land	**L3**
Land With Composite Landforms	**L4**
M. Lithology	
Igneous rock	**M100**
Igneous plutonic rock	**M110**
Granite	**M111**
Granodiorite	**M112**
Quartz diorite	**M113**
Syenite	**M114**
Monzonite	**M115**
Diorite	**M116**
Gabbro	**M117**
Foidic plutonic rock	**M118**
Ultramatic plutonic rock	**M119**
Igneous hypabyssal rock	**M120**
Aplite	**M121**
Pegmatite	**M122**
Porphyry	**M123**
Dolerite/diabase	**M124**
Igneous volcanic rock	**M130**
Rhyolite	**M131**
Dacite	**M132**
Trachyte	**M133**
Latite	**M134**
Andesite	**M135**
Basalt	**M136**
Phonolite	**M137**
Tephrite	**M138**
Pyroclastic rock	**M140**
Ash	**M141**
Lapilli	**M142**
Scoria	**M143**
Tuff	**M144**
Ignimbrite	**M145**
Lahar	**M146**
Agglomerate	**M147**
Other Igneous rock	**M199**
Sedimentary rock	**M200**
Unconsolidated clastic sed. Rock	**M210**
Clay	**M211**
Silt	**M212**
Sand	**M213**
Gravel	**M214**
Loess	**M215**
Loam	**M216**
Colluvium	**M217**
Shells	**M218**
Cons. clastic siliceous sed. Rock	**M220**
Mudstone	**M221**
Siltstone	**M222**
Shale	**M223**
Quartzararenite	**M224**
Litihic arenite	**M225**
Feldspathice arenite/arkose	**M226**
Graywacke	**M227**
Conglomerate	**M228**
Breccia	**M229**
Calcareous rock	**M230**
Marl	**M231**
Calcilutite	**M232**
Calcarenite	**M233**
Calcirudite	**M234**
Algal/reefal limestone	**M235**
Travertine	**M236**
Tufa	**M237**
Dolomite	**M238**
Evaporite	**M240**
Gypsum	**M241**
Halite	**M242**
Organic rock	**M250**
Peat	**M251**
Lignite	**M252**
Coal	**M253**
Tar	**M254**
Residual rock	**M260**
Laterite	**M261**
Bauxite	**M262**
Kaolin	**M263**
Other Sedimentary rock	**M299**
Metamorphic rock	**M300**
Contact metamorphic rock	**M310**
Hornfels	**M311**
Spotted slate	**M312**
Skarn	**M313**
Cataclastic metamorphic rock	**M320**
Cataclastic breccia	**M321**
Mylonite	**M322**

Land Cover Classification System	Code				
ENVIRONMENTAL ATTRIBUTES					
Regional-metamorphic rock	**M330**				
Slate	**M331**	Paleozoic	**M700**	O. Climate	
Schist	**M332**	**Permian**	**M710**	Thermal Climate	
Gneiss	**M333**	**Carboniferous**	**M720**	**Tropics**	**O1**
Migmatite	**M334**	**Devonian**	**M730**	**Subtropics - Summer rainfall**	**O2**
Granulite	**M335**	**Silurian**	**M740**	**Subtropics - Winter Rainfall**	**O3**
Eclogite	**M336**	**Ordovician**	**M750**	**Temperate Oceanic**	**O4**
Quartzite	**M337**	**Cambrian**	**M760**	**Temperate Continental**	**O5**
Marble	**M338**	Precambrian	**M800**	**Boreal Oceanic**	**O6**
Other metamorphic rock	**M399**	N. Soil Surface Aspect		**Boreal Continental**	**O7**
M. Lithology – Age Geol. Parent Mat.		Bare Rock	**N1**	**Polar Arctic**	**O8**
Quartenary	**M400**	Soil Surface	**N2**	Moisture Determined LGP	
Holocene	**M410**	**Stony (5 - 40%)**	**N5**	**Hyperarid**	**O9**
Pleistocene	**M420**	**Very Stony (40 - 80%)**	**N6**	**Arid**	**O10**
Late Pleistocene	**M421**	Loose and Shifting Sands	**N3**	**Dry Semi-Arid**	**O11**
Middle Pleistocene	**M422**	**Stony (5 - 40%)**	**N5**	**Moisture Semi-Arid**	**O12**
Early Pleistocene	**M423**	**With Dunes**	**N7**	**Subhumid**	**O13**
Tertiary	**M500**	Hardpans	**N4**	**Humid**	**O14**
Piocene	**M510**	**Ironpan/Laterite**	**N8**	**Perhumid**	**O15**
Miocene	**M520**	**(petro)Calcic**	**N9**		
Oligocene	**M530**	**PetroGypsic**	**N10**		
Eocene	**M540**	**Hardened Plinthite**	**N11**		
Paleocene	**M550**	N. Soil – Subsurface Aspect			
Mesozoic	**M600**	FAO's Major Soil Groups	**N12**		
Cretaceous	**M610**				
Jurassic	**M620**				
Triassic	**M630**				

Land Cover Classification System	Code
ENVIRONMENTAL ATTRIBUTES	
P. Altitude	
< 50 - 300 m	**P1**
< 50 m	**P5**
50 - 100 m	**P6**
100 - 300 m	**P7**
300 - 1500 m	**P2**
300 - 600 m	**P8**
600 - 1000 m	**P9**
1000 - 1500 m	**P10**
1500 - 3000 m	**P3**
1500 - 2000 m	**P11**
2000 - 2500 m	**P12**
2500 - 3000 m	**P13**
3000 - > 5000 m	**P4**
3000 - 3500 m	**P14**
3500 - 5000 m	**P15**
> 5000 m	**P16**

Q. Erosion	
No Visible Erosion	**Q1**
Visible Evidence of Erosion	**Q2**
Water Erosion	**Q3**
Sheet	**Q6**
Rill	**Q7**
Gully	**Q8**
Wind Erosion	**Q4**
Mass Movement	**Q5**
R. Water Quality	
Fresh Water	**R1**
Brackish Waer	**R2**
Saline Water	**R3**

U. Vegetation	
Scattered Vegetation Present	**U1**
Woody	**U2**
Herbaceous	**U3**
Forbs	**U5**
Graminoids	**U6**
Lichens/Mosses	**U4**
Lichens	**U7**
Mosses	**U8**
W. Crop Cover/Density	
Permanent Life Forms:	
Closed Cover > (70-60%)	**W1**
Closed Cover (70-60) - (20-10)%	**W2**
Sparse Cover <(20-10)%	**W3**
Temporary Life Forms:	
High Crop Density (> 60%)	**W4**
Medium Crop Density (60 - 30%)	**W5**
Low Crop Density (30 - 15%)	**W6**

3. Classification implementation within a GPS device

3.1 Introduction

One of the purposes of this project is to demonstrate the acquisition of data required for land use and cover classification using standard GPS equipment. Section 5 compares the range of GPS units available and highlights their applicability to the requirements of this project. Essentially what is required is the ability to record data about land use and cover in the field at specific sample point locations. Windows CE based GPS units offer the opportunity to develop bespoke data entry applications. However, the remit of this project requires the use of data entry products supplied as a standard product with the GPS unit. The following outline is therefore based upon this premise. A more in depth description of the database construction and data entry procedure is provided in Section 3.2.

Several mapping GPS devices offer a utility to facilitate data entry of attributes in addition to positional information. The terminology used to describe these utilities varies between manufacturers, for example, feature library (Thales/Magellan MobileMapper) or data dictionary (Trimble). However, the functionality offered is very similar. For the purpose of this study, the examples given will follow the implementation of the Trimble TerraSync software available on the Trimble GeoXT/XM GPS units.

The data dictionary is a flat file database used with the TerraSync software purchased separately with products such as the Trimble GeoXM and Geo XT. The database structure is formulated using the Pathfinder Office software product that can be purchased in addition to the GPS unit. The construction of the dictionary (Appendix A) consists of naming the data entry fields and for each field creating a list of potential data entries. The completed structure is uploaded to the GPS unit using the data communication program supplied with the GPS hardware. Field workers are then able to access the new data dictionary through the normal GPS menu interface.

Implementing a data dictionary for the land cover and use classification described above requires the user to enter data at each sample point, for each classifier. Data recorded is downloaded for subsequent analysis within suitable software packages, for example, the LCCS program, GIS software or databases.

3.2. Data dictionary background

A Trimble data dictionary contains a description of features, and their attributes, relevant to a particular data collection task. A data dictionary can therefore be considered a template for data collection. This template provides the outline for data collection tasks but does not store either the positional or the spatial attribute data of features which are stored in the Trimble rover file.

The data dictionary can be considered as being constructed from two elements, the features to be collected in the field, and secondly a list of attributes which describe each of these features.

Features:
Features recorded via a data dictionary can be described using either a point, line or polygon data structure. Feature descriptions can be edited to meet the project requirements and multiple features of the same type are permitted within a single dictionary definition.

Feature Attributes:
Attributes are feature specific and take the form of a series of data fields which accompany the standard GPS positional information. Fields can be designed to contain numeric or text data entries. In addition data integrity can be ensured with the implementation of drop-down selection and required fields during data assignment.

Data dictionaries are specific to Trimble and are therefore created in and used with the Trimble software range. Data dictionary design and creation is achieved within the Pathfinder Office software although import and editing functionality is also available within the TerraSync software. In addition to dictionary creation further functionality is added via the importing of data dictionary definitions using the structure of existing data sources, for example, Trimble data files or shapefiles.

As a result of this, construction of data dictionaries have the advantages of being able to provide a means of structuring data collection tasks, according to the required features of a survey, and ensuring data integrity, by specifying allowable data inputs. While data dictionaries do provide a more complete data collection solution, in comparison to a generic data collection template, several functionality restrictions can impact on dictionary design. Table 3.2.1 outlines some of the general advantages and disadvantages of data dictionary implementation.

Table 3.2.1 Advantages and disadvantages of data dictionary implementation

Advantages	**Disadvantages**
▪ Association of a features' positional and attribute information in a single file	▪ No context sensitive menu control
▪ Functionality to ensure standardised attribute recording	▪ No error checking capability to ensure logical attribute combinations
▪ Functionality to export coded rather than text descriptors	▪ Flat tabular output restricts number of data fields and database structuring
▪ Export data to multiple formats ▪ (via the Pathfinder Office software suite)	▪ Generic features cannot be excluded from the dictionary definition
▪ Ease of data dictionary modification within standard window based, user friendly, programs	▪ No help system, specific to the data dictionary can be developed in the standard software setup.
▪ Only limited training required to implement data dictionary based data collection	

The restrictions or disadvantages of using the data dictionaries as available in the Trimble TerraSync software could be overcome by the development of a bespoke software application, but this would imply longer development and such a software package would be more difficult to support.

3.3. Data dictionary development for land use and LCCS characterisation

The basis of the land use and LCCS characterisation developed for this project is the recording of classification category data related to each survey position. The following sections outline the design and development of a data dictionary for this collection task set within the constraints of the data dictionary functionality.

Feature definition
The main functionality limitation driving the data dictionary definition in this project is the lack of context sensitive menu controls. This has implications in that the variability of the classification category data and the hierarchical nature of the classifications are not easily accommodated. Within a bespoke application, an ideal solution, to encompass the variability of criteria and parameters, would be a single survey point feature with attribute recording based on a context sensitive menu system i.e. selection of preceding criteria would control the appearance of subsequent menus. As this is unavailable within the standard data dictionary, alternative approaches must be taken.

i) Land use
Definition of the land use feature is simple as the land use characteristics recorded are consistent across all sample points (Table 2.1). As a result the land use attributes can be attributed to a single land use characterisation feature.

This separate feature approach, as opposed to the inclusion of the land use classifiers within the pre-existing LCCS structure, is proposed as it ensures the data dictionary is focussed on land use, the primary objective of the survey. Additionally it reduces the need for lengthy data collection forms which would result from a combination of the land use and LCCS attributes. A potential shortcoming of this approach is the requirement for the surveyor to collect multiple features at each sample point (one feature for land use and one feature for land cover (LCCS)). Time implications of this double recording are minimised via a reduction in the GPS data collection time for the LCCS feature, the minimum number of GPS positions are reduced from 120 to 30. Data output from this multi-feature approach will separate the land use and cover data for each sample point, however, it is anticipated that simple GIS techniques can be used to merge the data if required.

ii) LCCS
To enable LCCS characterisation, more complex feature definition is required as the attributes recorded are dependent on previous stages in the classification hierarchy. Within the data dictionary this parameter variability can only be removed via the explicit definition of several features. These features must be defined to maximise feature variability so as to minimise within feature attribute variability and avoid drop down menus that are overly long. In terms of LCCS this is achieved by defining feature types based on the third dichotomous phase of the hierarchy.

Using the third dichotomous phase the resultant data dictionary point features are,

- Cultivated and Managed Terrestrial Area(s)
- Natural and Semi-Natural Terrestrial Vegetation
- Cultivated Aquatic or Regularly Flooded Area(s)
- Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation
- Artificial Surfaces and Associated Area(s)
- Bare Area(s)
- Artificial Water Bodies, Snow and Ice
- Natural Water Bodies, Snow and Ice

(Greyed items are not available in the current demonstration data dictionary, see figure 3.3.1.)

These features meet the requirement that attribute data fields and criteria are static. If the features were derived from any higher level of the LCCS hierarchy this requirement would not be met. For example, a feature defined as terrestrial at the second level of the hierarchy could be "Cultivated and Managed" or "Natural and Semi-natural Vegetation", as the required data attributes for these cover types varies they cannot be accommodated and hence are split into the two feature types.

Definition of features at the third hierarchical level does mean that not all levels of the LCCS classification are implicitly recorded. However, from the features at the third level all previous hierarchical elements can be implied so no information is lost. Although not recorded, the surveyor must use knowledge of the previous hierarchical levels to decide which feature type is the most appropriate for each survey point.

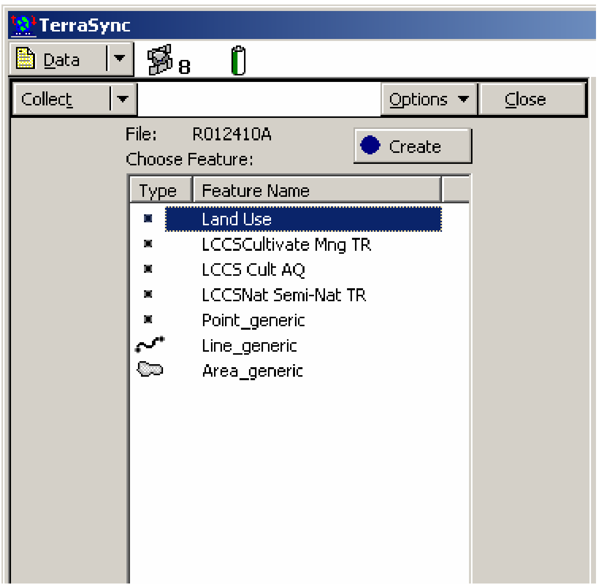

Figure 3.3.1. TerraSync feature selection form of a rover file implementing the LCCS and land use demonstration data dictionary

The preceding discussion implies that the data dictionary only contains the features relating to the LCCS and land use elements. A limitation of the data dictionary, however, means that additional, default, features are also available from the data collection menu of TerraSync (Figure 3.3.1). These default generic features contain no data collection parameters other than feature identification and are primarily used for positional recording. As these features are not relevant to the current survey task they would ideally, for neatness and consistency, be removed. However, this is not possible. Surveyor training or a user guide is therefore required to identify these spurious features and inform the user that they should be ignored during data capture.

Attribute and criteria recording

The third dichotomous level features of LCCS and the land use classification are each characterised by a series of attribute fields each of which are represented in the data dictionary.

Each attribute field contains a series of criteria represented by a text descriptor and unique code (Table 2.1). Using the built in functionality of the data dictionary, data input can be standardised by presenting the surveyor with data field specific, drop-down, attribute lists. Such an approach ensures that the surveyor can only input valid criteria and eliminates potential errors arising from spelling or data input mistakes. A limitation of the Trimble data dictionary is that these drop-down menus are hardwired on data dictionary creation and are not context sensitive. As a result variables in drop-down menus cannot be refined based on preceding selections resulting in lengthy drop-downs and perhaps more seriously inappropriate data entry as no error checking, against previous attributes, is available. No solution to this issue has been found for the current data dictionary. The definition of appropriate default values for drop-down menus and menu clarity, in terms of sections and sub-sections indicated by "----" marks (Figure 3.3.2), may reduce errors resulting from illogical criteria combinations but this is not a rigorous solution.

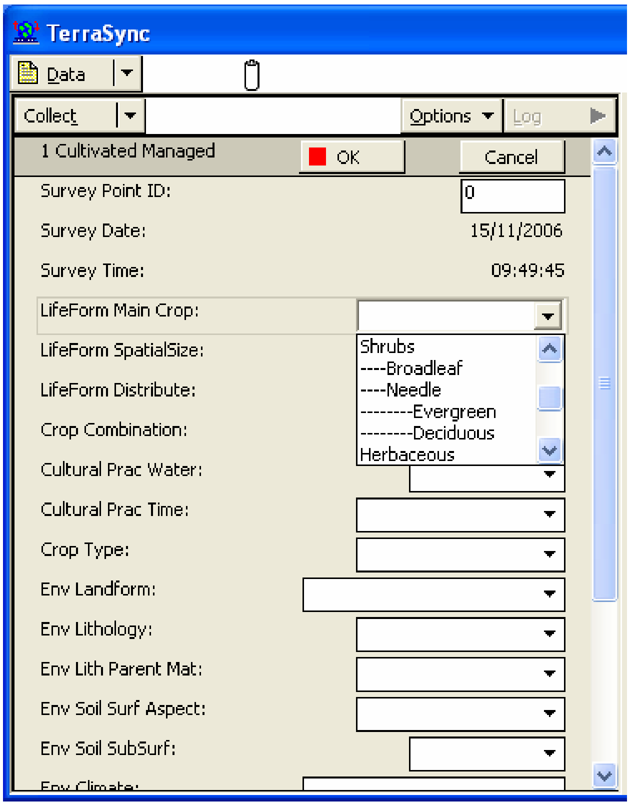

Figure 3.3.2. TerraSync feature attribute collection form (attribute fields reflect the selected feature type of 'Cultivated and Managed').

In addition to drop-down menus, data input can be further standardised by the definition of required fields. If an attribute field is marked as required within the dictionary definition, data must be input during feature creation. While this would initially seem advantageous care must be taken in required field definition as drop-down menus must be exhaustive. This may mean that an additional criterion of “Not Applicable” needs to be added. The addition of this criterion however implies that the surveyor can bypass required fields and not record essential data elements.

A further consideration when setting required fields is their ease of use within TerraSync. After initial criterion selection, required field drop-down menus are locked. In the case of erroneous data entry these fields will remain locked until all required fields have appropriate values specified, only then can erroneous entries be re-entered.

A requirement of the data dictionary design is that a surveyor has background knowledge of the land use classification and LCCS in terms of its hierarchical structure and the attribute fields. This is to ensure acquaintance with attribute definitions and appropriate data entry combinations. This is particularly important as a limitation of the data dictionary design is that no or limited explanatory text can be added to the data input screen to aid data collection in the field. It is in this context that the functionality of the GeoXT/XM Windows CE environment should be further explored in the development of a stand-alone help guide or data collection manual.

Data storage and export

For ease of use the attribute drop-down menus are populated with text descriptions for each criterion, as specified by the land use classification and LCCS. While descriptors are most appropriate to aid data input the criterion codes may be more applicable in terms of data storage and further data processing. An advantage of the Trimble data dictionary is functionality that allows relationships to be developed between the text descriptors or drop-down menu labels and coded values. During export of the data, to various formats via the Pathfinder Office software, attribute fields can be exported with the text descriptors or coded values.

Table 3.2.1 states that a disadvantage of the data dictionary is the flat nature of the data storage table. This is particularly the case if extensive, multi-scaled measurements are required at each survey location. Within this survey the recorded data is not sufficiently complex to require a relational database structure and therefore the flat table does not limit the data dictionary design or implementation.

Data output

From within the Pathfinder Office software it is possible to export the Trimble data file, created from the original rover file, into various formats (Appendix B). As specified previously, during export the format of the criteria, text or code must be specified in addition to the required tabular fields. By default all feature attribute fields will be exported. However, the surveyor must specify which, if any, GPS derived fields are required. This export process will result in a series of data files where each file represents the land use or LCCS feature. Further modification of these files is largely a function of the export format.

3.3 Bespoke application development

Bearing in mind the limitations of the data dictionary approach, a prototype bespoke application was developed based around the LUCAS 2003 methodology (see section 4.4).

The application demonstrates that it is possible to develop such a tool, but its full implementation would require a considerable amount of programming beyond the scope of this feasibility study. Details of the application development and testing are described in Appendix C.

Due to the considerable amount of programming required in bespoke application development, an intermediary solution may be sought. Currently available freeware which has the potential to support this solution is the CyberTracker software suite (www.cybertracker.co.za).

CyberTracker

The CyberTracker software suite enables the development of an application specific field data collection system for implementation on a Mobile PC with integrated GPS.

Application development is via a Windows interface in the CyberTracker Standard or Professional desktop software. Within this software field data collection application development and testing is considerably less complex, in comparison to bespoke programming, with complicated program development hidden behind 'single click' solutions.

Applications developed within the CyberTracker software are based on a series of data collection screens the design and sequence of which is user defined. Multiple screen templates, including lists, check boxes and text input, allow for the collection of data in various formats. To ensure concise screen design data collection is based on a sequence of data collection screens, which step through the predefined data collection tasks. A major advantage of this approach is functionality to enable the screen sequence to be based on preceding data input.

The CyberTracker software contains functionality to enable the integration of field data collection with GPS location recording. This data is recorded as a single point or track, a series of points created as the surveyor moves. A current limitation of GPS integration, within the software, is that GPS recording represents only a single point measurement. An ideal solution would enable the recording of multiple positions averaged to provide a more accurate location estimate.

Once designed on the desktop PC the field data collection application is uploaded onto a mobile device. Subsequent to data collection data is viewed in the desktop CyberTracker software from which export options are available to allow transfer of this data into standard GIS software.

The CyberTracker software suite is primarily designed for conservation and ecological data recording. As such, further investigations are required to determine the applicability of this software to the collection of land use and cover data within the outlined structure. The software is advantageous, over the standard GPS software, as it allows a greater flexibility of screen design with context sensitive screen sequences.

However, the recording of GPS location from a single point measurement is not recommended. Adaptations to the software to allow the averaging of multiple records for each point should be investigated to improve GPS location accuracy.

Such investigations are outside the remit of this feasibility study and hence are recommended as further work.

4. Sampling strategy

4.1. Background

The implementation of the classification approach described above although mainly centred around a point sample could be applicable to both a list frame or an area frame sample, the point surveyed could then be assimilated to either the middle of a parcel as part of an area frame sample or the farm in the case of the list frame approach.

It is understood that a complete census would not be appropriate as the cost would be prohibitive and that the type of sampling to be applied should allow the calculation of the precision of the estimates derived. These types of surveys are called probability sample surveys (FAO 1996) and are usually defined according to the way in which the sampling units are identified: These are:

- List frame survey: Sample units are drawn from a list of land owners typically identified by their name and addresses. These types of surveys have traditionally been used extensively for agricultural statistics (FAO 1996) and are used in a number of European countries. However, to be reliable, the list requires frequent update. The list is particularly difficult and expensive to update when there are a very large number of land owners and where communications are not well developed. As this is clearly the case in an African context, these types of survey are not recommended within the scope of this study
- Area frame survey: Sample units correspond to areas of land which are often referred to as segments. The entire study area is divided into non-overlapping segments and a selection is drawn from the total population to derive the sample. Depending on the type of segments, area frame surveys can be further sub-divided into:
    - Segment with identifiable boundaries
    - Square segments
    - Point sample

The area frame sample approach is one that is better suited to this type of work because it does not require any *a priori* knowledge of the stakeholders as is the case for list frame surveys.

4.2. Segment with identifiable boundaries

This type of approach has been widely applied in many countries notably the United States (Cotter and Nealon, 1986) as part of the yearly June Agricultural Survey and Italy (FAO, 1998; Carfagna, 1998).

The identification of segment boundaries relies on delineating existing physical and administrative boundaries. This means that segments follow an irregular pattern determined by, for example, rivers, roads, and hedges.(Figure 4.2.1).

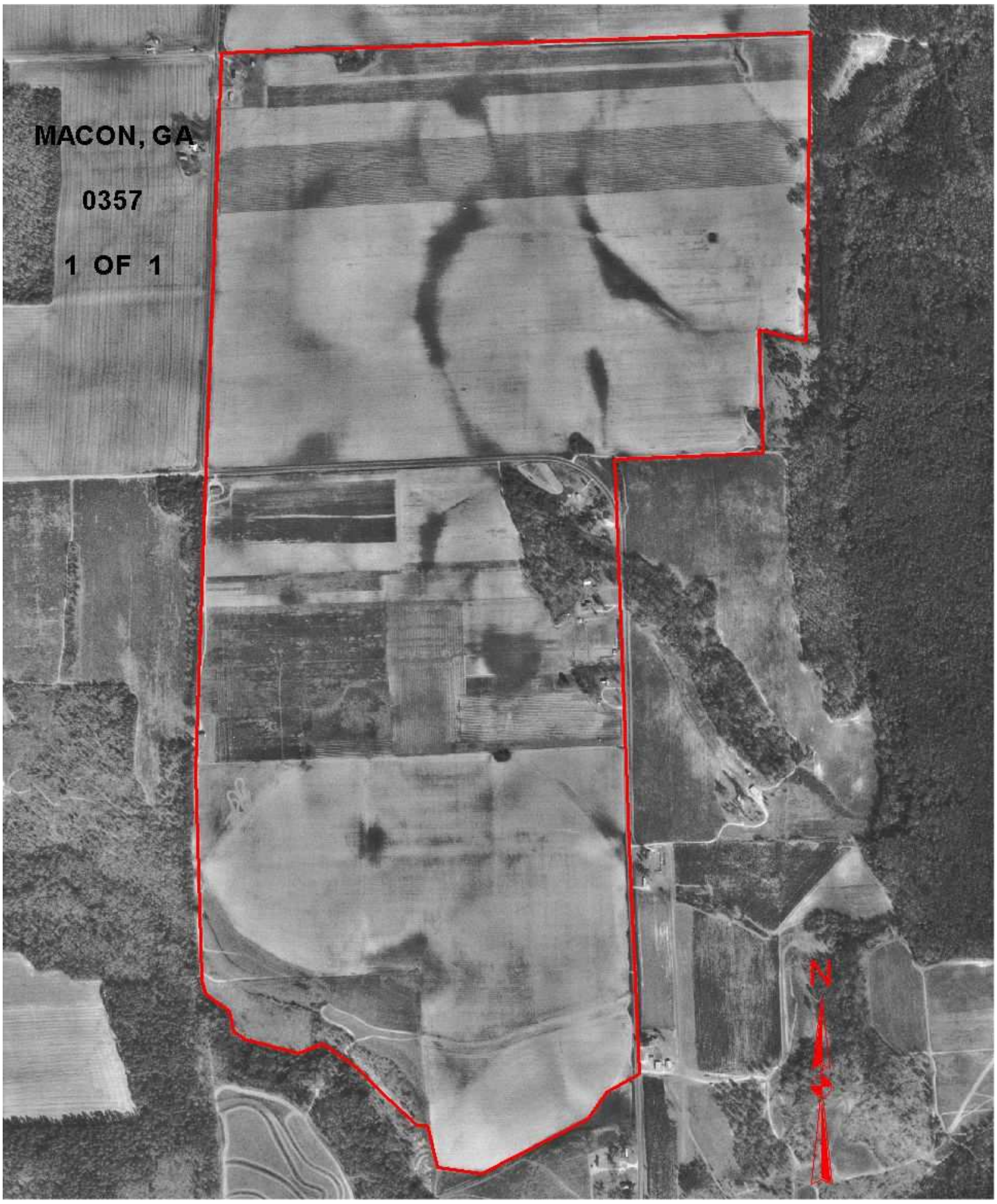

Figure 4.2.1. Segment with identifiable boundaries *(http://www.nass.usda.gov/research/seg0357.jpg)*

It has been successfully applied in the United States where field boundaries and roads tend to follow a regular grid pattern and although it has also been applied in Europe, its implementation was made more difficult because of the more irregular field patterns making it difficult to identify segments of similar size.

The advantage of the method is that the segment size coincides with the parcel size and relying on physical boundaries makes it easy to identify in the field. Moreover, despite the initial high cost of developing the segment database, it can be reused every year and it can also be combined with a remote sensing approach facilitating the digital classification of satellite imagery by making parcel based classification much easier to implement.

In an African context, parcel boundaries are sometimes very difficult to identify or are non existent, making the implementation of this approach almost impossible.

4.3. Square segments

In order to overcome the issues of the approach outlined above, a simplified approach was developed making use of a square segment with artificial boundaries purely defined on the basis of the map grid without any consideration for any physical boundaries.

The only requirement linking square segments to their physical environment is to ensure that the size of the segment is such that no more than 50 and no less than 10 parcels are present (Gallego, 1995). Therefore, keeping the same sampling intensity, implementing a square segment survey in a landscape with small parcels will result to a larger number of smaller segments compared with a landscape where larger parcels occur.

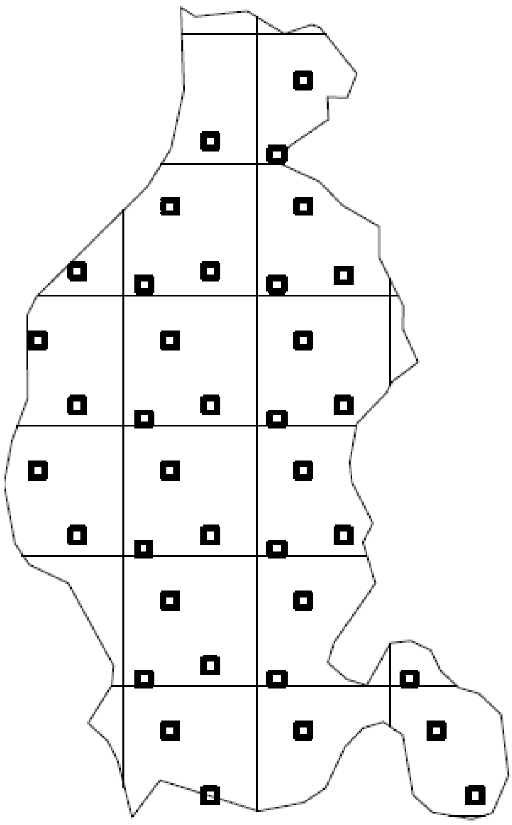

Figure 4.3.1. Randomly aligned systematic sample

Samples are typically drawn from the combination of the study area boundaries and a grid which is used initially as a series of blocks (Figure 4.3.1). The size of each block is a multiple of the segment size and is determined according to the desired sampling intensity. The initial position of the grid is selected randomly. The position of a segment in a block is selected at random and this position is repeated across the study area ending up in a randomly aligned systematic sample. A second and third position can be selected as shown in Figure 4.3.1. These successive positions are known as replicates. The use of replicates is particularly useful in the context of stratification when different sampling rates need to be used (e.g. one replicate is used in mountainous areas and three replicates are used in densely populated rural areas).

A systematic sample is often preferred, compared to a pure random sample because it is a lot easier to implement over a large area and there is no bias introduced unless the spacing between segments coincides with regular variations in the landscape. This is unlikely to occur in most landscapes and perhaps even less in African landscapes.

Although square segments are largely used throughout Europe particularly following the Monitoring Agriculture with Remote Sensing (MARS) programme (Taylor et al., 1997), they would still require the delineation of parcel boundaries inside the segment (Figure 4.3.2.), which would again present substantial difficulties in most African contexts.

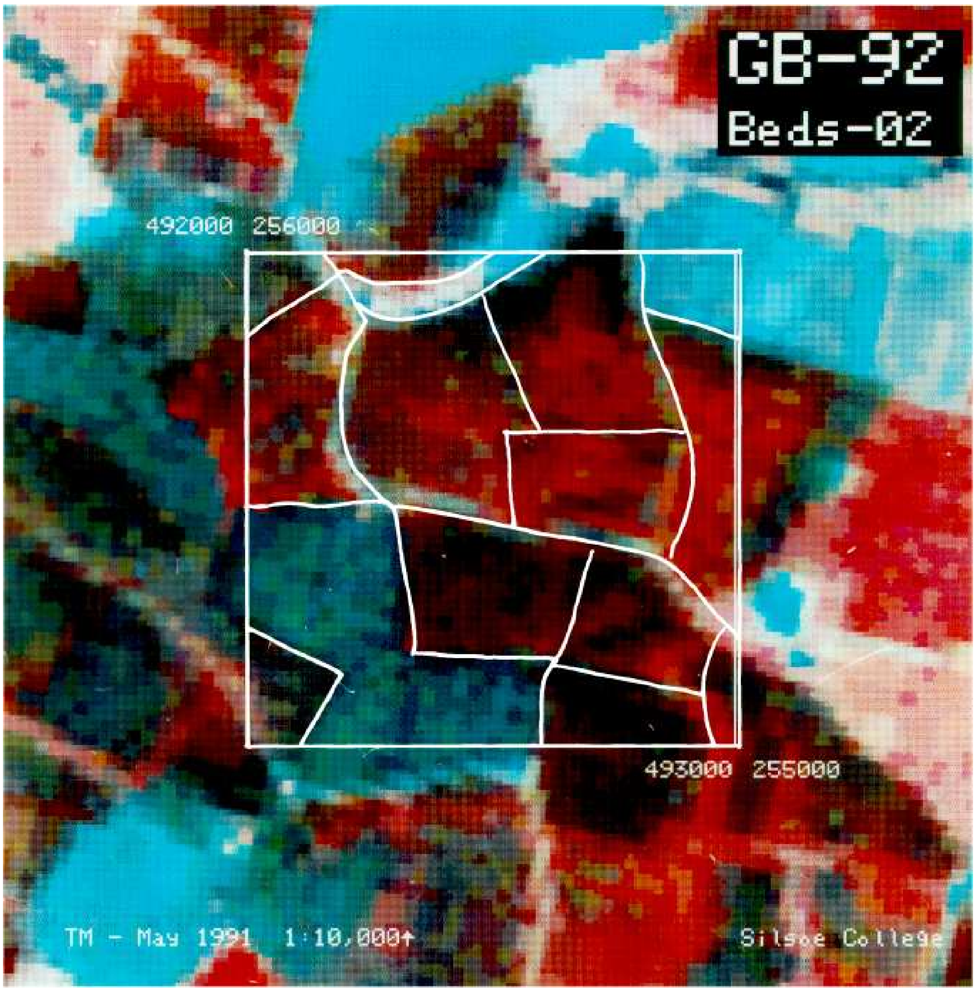

Figure 4.3.2. Example of a square segment with field parcels

4.4. Point sample

The point sample relies on the definition of a series of sample locations positioned around the study area. Although these locations are referred to as points, they usually cover a small area typically 9 m^2 in the case of the TER-UTI survey in France (Gay and Porchier, 2000) or the LUCAS survey for Europe (Delincé, 2001).

Both TER-UTI and the initial LUCAS surveys (2002-2003) consist of a clustered sample and rely on a two stage sampling. The initial stage defines the Primary Sample Units (PSUs) which can be assimilated to square or rectangular segments. The second stage defines the Secondary Sample Units (SSUs) which normally consist of a grid of points within the PSU as shown in Figure 4.4.1.

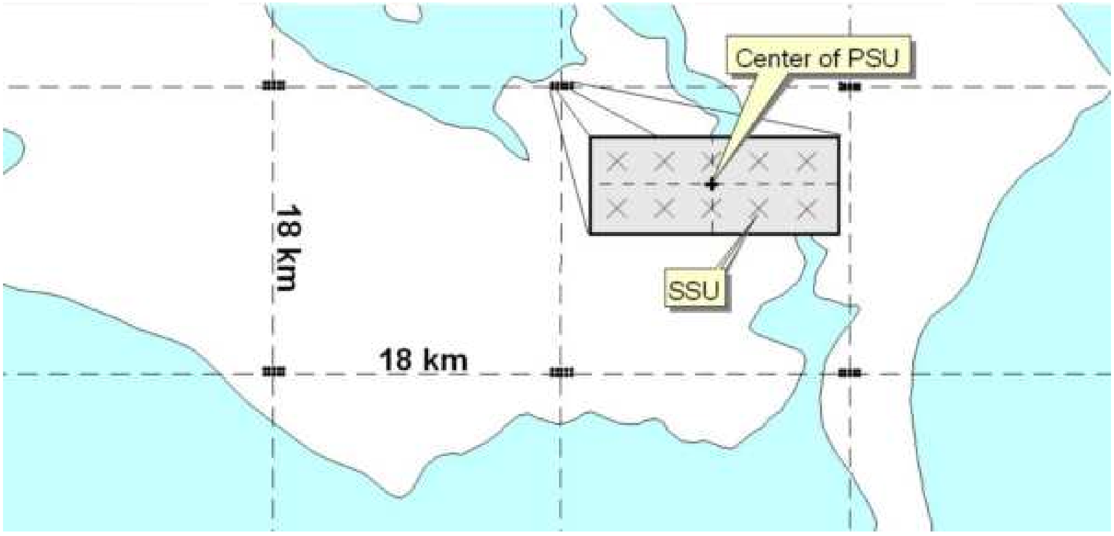

Figure 4.4.1. LUCAS 2002-2003 sample design (Delincé, 2001)

As discussed by Delincé (2001), the use of a clustered sample presents a way of reducing the variance of the final estimate. However, another way to achieve the same goal is to undertake a stratification (discussed in the next section). This was the approach adopted as part of the new LUCAS methodology implemented from 2005. Instead of a clustered approach, the sampling grid is based around the Lambert Equal Area coordinate system for Europe. The LUCAS master sample is defined by the intersection of the grid every 2 km for even coordinates (LUCAS, 2006). The master sample is then combined with the country boundaries, and a Digital Elevation Model (DEM) is used to exclude areas above 1200m elevation.

Each point is then photo-interpreted in one of seven strata with the help of recent digital orthophotographs or, if not available, satellite imagery and the Corine Land Cover 2000 data set (CLC2000). Each stratum is sampled at a different sampling rate to maximise the efficiency of the stratification (see table 4.4.1). The rationale for selecting the different sampling rates is primarily based around the land cover/use types that are more critical to characterise (i.e. agricultural land cover/use types in this case) thus resulting in more precise estimates for agricultural land use/cover types whilst maintaining costs to a reasonable level. A secondary reason is that it tends to put less emphasis on land cover/use types that are less likely to change over time.

It has been shown that the new approach brings an overall reduction of the variance by a factor of three and avoids the problem of incomplete PSUs (LUCAS, 2006). Moreover, Farmer (2005) demonstrated that there was no significant increase in the survey time with a one stage systematic sample compared with a 2 stage clustered approach. This was confirmed with the initial trials of the new LUCAS methodology which appear to suggest that survey costs will be less than with the 2 stage approach (LUCAS, 2006).

Table 4.4.1. Sampling rates applied by stratum (LUCAS, 2006)

Stratum	Sampling rate
Arable Land	50%
Permanent Crops	50%
Grassland	40%
Woodland, Shrubland	10%
Bare Land	10%
Artificial Areas	10%
Water	10%

The sample is drawn by grouping sample points on a 9 by 9 basis thus resulting in blocks of 81 points. Each replicate is selected randomly ensuring that successive replicates are not next to one another and its position repeated across the grid. Each replicate is selected up until the correct number of points is selected for each stratum according to the sampling rate identified in table 4.4.1.

Appendix D describes the implementation of the 2 LUCAS approaches for Sierra Leone. The LUCAS 2003 approach results in 220 PSUs with a total of 2200 SSUs while the 2006 approach would result in 7427 sample points by applying exactly the same sampling rates as the ones used for Europe. This is based on applying a stratification derived from The Global Land Cover (GLC) 2000 classification (Global Land Cover 2000, 2003). This was used as an example and in practice a more detailed assessment of each point should be done based on the interpretation of satellite imagery and/or aerial photography.

Point sampling is particularly suitable to the African environment because it does not require the identification of parcel boundaries as is the case for the other approaches. Secondly, because it is point based, it is also particularly suited to the use of a GPS data collection device as there is a direct link between the GPS position and the point sample.

4.5. Stratification

As mentioned above, stratification is one of the methods used to reduce variance by varying the sampling intensity depending on the stratum, e.g. there is no need to have a high sampling rate in water areas or bare areas because there will be little variation in terms of land use; however, there will be a need to increase the sampling intensity in areas where there will be a high level of variability such as agricultural areas.

In theory, stratification is seen as a good thing, but it is often very difficult to implement as there are few datasets of sufficient precision and quality available to assist with its implementation. If the stratification is applied using information that is not sufficiently precise and reliable, then the outcome is likely to be worse than if no stratification is applied. Therefore, stratification should only be applied based on criteria that can be easily verified or measured. One such example would be elevation: areas above a certain elevation can be excluded using a DEM. Another example could be water features.

In the case of the new LUCAS methodology, the problems posed by stratification were overcome by the photo-interpretation of sample locations into seven strata. This approach could also be recommended in an African context as it has the added advantage of offering a substantial reduction of the sample size in areas where accessibility is often a problem.

4.6. Recommendations

The benefits of a GPS based field data collection system would be maximised if it was used as part of a point frame sample.

The approach adopted as part of the 2006 LUCAS methodology is particularly interesting as it would combine the use of remotely sensed data for the stratification stage with the implementation of a field survey. The methodology would need to be adapted with notably the use of strata definition more representative of the local conditions.

The LUCAS 2006 approach implemented in Sierra Leone as described in Appendix D results in more than 3 times the number of samples as the 2003 approach, but this may be because the sampling rates applied need to be adjusted to the Sierra Leone conditions. This could result in a more manageable number of points, but the stratification criteria would need to be clearly identified and discussed to ensure they can be easily photo-interpreted and are relevant to African conditions. As such it would be advisable to carry out a pilot study over a small region (perhaps based on administrative units) to test the methodology

However, the implementation of such an approach would also mean that sufficient resources are available to carry out the photo-interpretation stage in terms of remotely sensed data availability and technical expertise for the interpretation. If these resources were not available, then the initial 2002 LUCAS methodology using a 2 stage clustered sample could be implemented.

5. Field data collection system

5.1. GPS concepts

The Global Positioning System (GPS) was the first worldwide Global Navigation Satellite based System (GNSS). Other systems have subsequently or are being developed, for example, GLONASS in Russia and Galileo in Europe which is still a few years from being operational. GPS relies on a constellation of 24 satellites placed in very precise orbits which are closely monitored from the ground (figure 5.1.1). Each satellite carries onboard a very precise atomic clock allowing a user with an appropriate receiver to measure the time delay for a standardised signal to travel from the satellite to the receiver. The accurate knowledge of each GPS satellite orbit and the combination of time delay measurements from at least 4 satellites makes it possible to calculate an accurate position on the Earth's surface (a position can be computed from 3 satellites, but a 4th one is required to resolve the uncertainty caused by the fact that the receivers' clock is not very accurate).

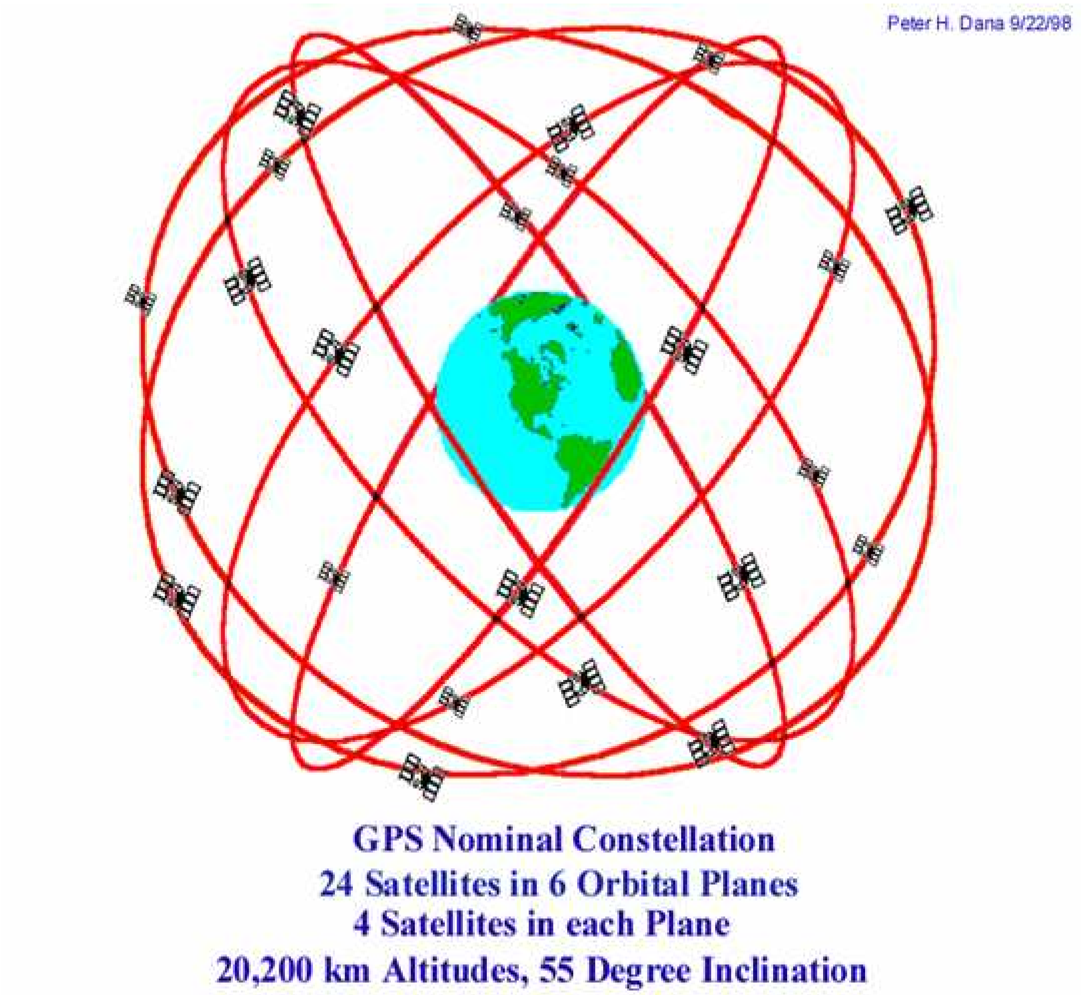

Figure 5.1.1. GPS constellation.

Standalone GPS units should be capable of accuracies within 15-30m with a clear view of the sky (e.g. tree canopy can affect GPS accuracy). GPS positions can be improved using a technique called Differential GPS (DGPS) which relies on having a second unit placed at a known position (base station) which will monitor the errors associated with each satellite. This information can either be broadcast in real-time to the mobile unit or stored on a computer for processing once the mobile unit has collected data in the field.

DGPS can achieve accuracies as small as a few cm with the most sophisticated equipment, but are typically capable of 2-5m using standard equipment.

A more transparent implementation of DGPS from a user point of view are the Satellite Based Augmentation Systems (SBAS) which rely on a network of base stations over a large area (continental level). The information is then combined into a single signal compatible with SBAS enabled GPS receivers which is broadcast via a geostationary telecommunication satellite. There are currently 3 SBAS being developed around the world: WAAS (Wide Area Augmentation System) in North America, MSAS (Multi-function transportation Satellite-based Augmentation System) for Japan and EGNOS (European Geostationary Navigation Overlay System) for Europe.

Accuracies with SBAS enabled receivers are of the order of 2-5m. There are plans to extend EGNOS for the African continent, but this is not yet operational as the signal currently generated over Africa would not offer any significant improvement on the standalone GPS signal as shown in figure 5.1.2.

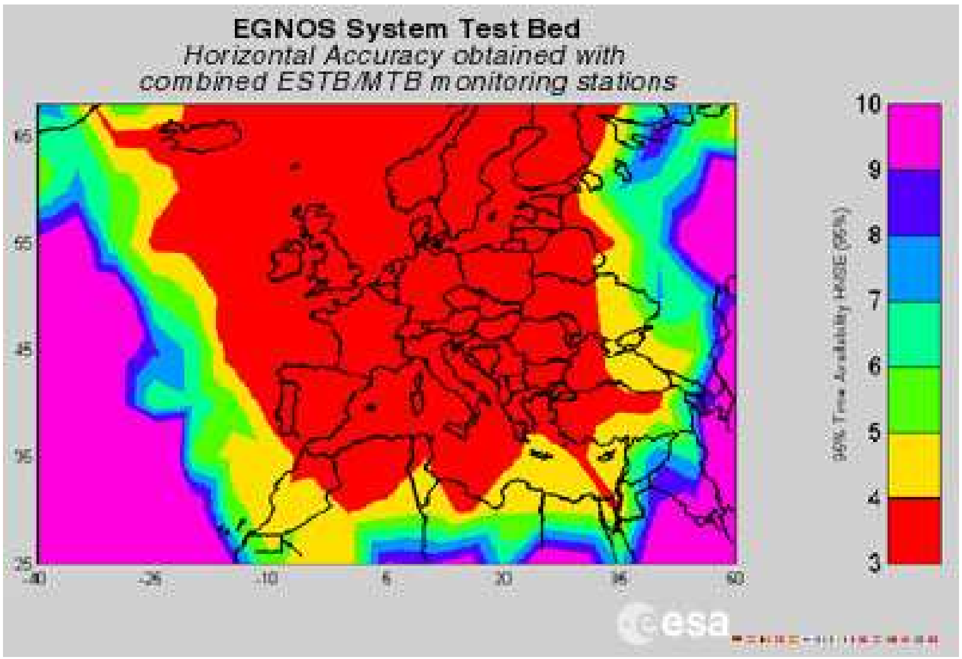

Figure 5.1.2. Map of EGNOS coverage and estimated accuracy.

5.2. Low cost handheld GPS

GPS receivers have now become widespread in the field of recreational and outdoor activities. Units such as the ones shown in figure 5.2.1 can be purchased from one hundred to a few hundred US$ depending on the unit’s functionality, amount of memory and pre-loaded data. Some units can provide detailed mapping for a given area making them particularly powerful navigation devices.

Data collection capability is limited to recording waypoints (point locations that can later be used for navigation purposes, e.g. you can record the location of your vehicle when hiking) or the receiver can be set to record your position at regular intervals whilst moving and this can be displayed on the GPS screen, saved and even exported to a PC with a suitable interface cable for use in other programmes. However, although you can give a meaningful name to waypoints and recorded tracks, there is no capability to record complex characteristics at a point location as would be required for the purpose of this application.

Therefore, the use of low cost handheld GPS for land use surveys should only be used as a backup solution to navigation to point locations combined with pen and paper to record detailed land use characteristics.

Figure 5.2.1. Examples of low cost handheld GPS receivers.

5.3. PDA GPS

Recently, the development of GPS devices that can be connected to a Personal Digital Assistant has been extremely fast. It is now possible to connect a standard PDA to a GPS add-on using a cable or even a wireless Bluetooth connection. Some PDAs even have an integral GPS antenna and receiver providing an all-in-one solution. Examples of PDA GPS are shown in Figure 5.3.1.

PDA GPS can be associated with GPS recording software and are still very cost effective as they cost as little as a couple of hundred US$ to which the cost of the software needs to be added, but this is still very attractive pricing. Their main drawback is that they are not as rugged as handheld GPS and are more suited for use inside a car or for very occasional outdoor use. More ruggedised models are available, but their cost is much higher and comparable with mapping GPS units described below. The main difference is that they do not provide a fully integrated solution, (i.e. the GPS component needs to be integrated with the PDA requiring the connection of each type of equipment together and a software package also needs to be purchased, installed and configured separately). This would be a disadvantage for land use surveys.

Figure 5.3.1. Examples of PDA GPS.

5.4. Mapping GPS

GPS manufacturers have developed a range of GPS units which combine GPS receiving capability with the ability to acquire GIS ready features in the form of points, lines and polygons. It is also possible to include detailed characteristics associated with each feature that can be selected from a drop down list. These characteristics are stored in a data dictionary which can be customised using the accompanying software installed on a PC. The data dictionary can then be uploaded to the GPS to be used in the field.

There are 3 types of mapping GPS device:

- Separate GPS receiver, GPS antenna and data logging devices using a field computer: These units offer the greatest level of accuracy and flexibility, but are also the most expensive. They would be too costly and complex to configure and operate for the purpose of a land use survey. Units amount to around US$10,000

- Integrated GPS units running the Windows CE operating systems: These units are fully integrated combining the GPS receiver, antenna and data logger into a single handheld unit. However, they still offer the capability of connecting to a separate GPS antenna for better accuracy. Examples of such units are the Topcon GMS-2, Thales/Magellan MobileMapper CE and Trimble GeoXM/XT (Figure 5.4.1). In addition to the cost of a unit (at least US$2500), the cost of the GPS data collection software, PC interface and configuration software need to be added.
- Integrated GPS unit running proprietary software: These units are less configurable than the above, but have the benefit of being much cheaper at less than US$2000 for a Thales/Magellan MobileMapper (shown in figure 5.4.1.).

Figure 5.4.1. Examples of handheld Mapping GPS units (not to scale relative to one another).

Differential GPS could be implemented with two mapping GPS units with the aim to improve the precision as described in section 5.1. This second unit would then be placed at a fixed known location for the duration of the field work. GPS data are recorded by both units and downloaded to a PC with GPS processing software installed (such as Trimble Pathfinder Office or Thales/Magellan Mobile Mapper Office). The field unit data is then post-processed with the base station data to achieve a higher level of accuracy.

The level of accuracy that could be achieved varies primarily on the type of processing applied and the distance between the field unit and the base station.

The highest accuracy would be achieved with ‘carrier phase’ processing and can be obtained using a suitable GPS unit and associated software (such as the Trimble GeoXT and TerraSync Pro or Magellan ProMark III) to decimetre level provided that the field unit is less than 100km from the base station.

Metre level accuracy would be achievable with most mapping GPS units using ‘code phase’ processing provided the field unit is less than a few hundred km from the base station.

If real-time processing was necessary, this would require the acquisition of additional equipment to create a radio link between the field unit and base station. However, because of the extra processing required, this would only be possible with ‘code phase’ units and limited to metre level accuracy.

5.5. Recommendations

To meet the requirements of a land use survey as defined in the previous sections, a mapping GPS device running Windows CE would be recommended. If higher positional accuracy was required with the use of post-processing differential correction, the configurations below for packages 1, 2 and 3 (package 4 is excluded as standard GPS units are not capable of storing detailed GPS data) can still be considered with the acquisition of an extra unit to be used as a base station:

Package 1

- Trimble Geo XM
- Trimble Terrasync Professional software
- Trimble Pathfinder Office software

This unit provides a large amount of memory and can be easily configured to meet the requirements of the land use survey, but the total cost is likely to exceed US$5,000.

Package 2

An alternative is:

- Thales/Magellan MobileMapper CE
- ArcPad software

It has similar characteristics the Trimble unit but does not have as much memory and would cost less, at around US$3500.

Package 3

The MobileMapper unit at around US$2000 is another realistic alternative, but would not offer the capability to display satellite images as an image backdrop (only vector data can be displayed).

Package 4

Finally, simple handheld GPS could be used as a backup/low cost solution, but only GPS position can be recorded. Land use information would have to be recorded on paper. GPS PDA would offer the capability of recording land use characteristics as well as GPS positions, but these units are not sufficiently rugged.

6. Conclusions

The technology for a GPS based field data collection system for agricultural land use now appears sufficiently mature and affordable for such a system to be implemented in an African context. However, the benefits of such a system will only materialise if the following factors and stages are satisfactorily met and correctly implemented:

- The needs for the collection of such data must be clearly established at the political level. This could perhaps be facilitated by the implementation of a pilot study over a limited area to demonstrate the value of the information gathered.
- An appropriate classification scheme will need to be derived translating the needs expressed at policy level in terms of the data to be acquired in the field. It is expected that there is likely to be an iterative process between policy requirements and the data gathered. Therefore, it is necessary to adopt a flexible approach in terms of the data acquired. This will be best achieved if a classifier approach such as the one developed as part of the FAO LCCS is extended to the acquisition of land use data.
- The implementation of such a classification scheme in an off-the-shelf GPS field data collection device is possible, but as shown in this report will result in a number of limitations linked to the difficulty of implementing different hierarchy levels. This could be solved by the development of a bespoke application, within a programming environment or currently available freeware i.e. CyberTracker, but to the detriment of the level of future support that would be available for the application developed.
- To be fully beneficial, the GPS field data collection system would need to be combined with an area frame sampling strategy based on a point sample as implemented as part of the LUCAS 2006 survey in Europe. The methodology would need to be adapted to African conditions particularly with respect to the stratification approach and would require building capacity in terms of remotely sensed data interpretation.
- From the GPS devices reviewed, it would appear that the Trimble GeoXM unit combined with the TerraSync Professional and Pathfinder Office software packages are best suited for this kind of work whilst offering a high level of flexibility. The Thales/Magellan MobileMapper unit offers a realistic lower cost alternative, but with a slightly lower level of flexibility.

The implementation of the above recommendations will require extensive training at every stage of the methodology.

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Appendix A

Appendix A

Land Cover and Land Use Survey:

Data Dictionary Definition Manual

1. Introduction

This manual outlines the definition of a data dictionary for subsequent implementation in a GPS (Global Positioning System) survey (Appendix B). The manual will focus on the creation of dictionary within Pathfinder Office for subsequent implementation within the TerraSync software, on a Trimble GeoXT or GeoXM device. As the manual is intended only as a brief introduction to data dictionary creation, the reader is referred to the Pathfinder Office manual for further information.

Software and Hardware requirements

The following components are required to follow the manual:

- Trimble Pathfinder Office installed on a Windows PC

2. Pathfinder Office

Pathfinder Office is the PC based software that accompanies Trimble GPS units (needs to be purchased separately). This software provides tools which enable users to plan GPS surveys and successfully download and process the resultant data.

Creating a Pathfinder project

The Pathfinder Office software is based on the concept of projects. Whenever the software is in use the processing tasks must be completed within a project. These projects represent a good way of organising data.

Prior to data dictionary creation and editing a Pathfinder project must be created.

- Open Pathfinder Office from the Start Menu or desktop icon

On opening Pathfinder Office the “Select Project” window should open automatically, if it does not open then select *File/Projects*.

From the “Select Project” dialog you can open an existing project, if a suitable project for your current work has been created, or create a new project.

To create a new project

- Click 'New' at the base of the dialog to open the project folders dialog (Figure A2.1).

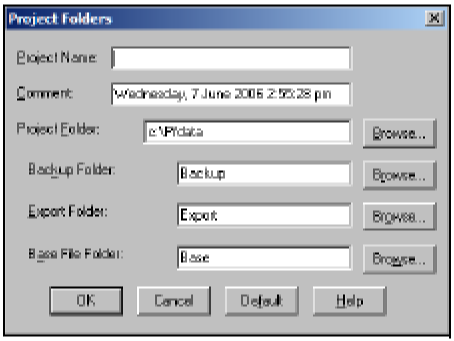


Figure A2.1 The Create new project dialog

- Specify a Project Name. Note that a series of invalid characters exist when specifying this name these include characters such as +, >, ? and "
- Press Enter or click in the next input field to accept the new project name.
- The Project Folder field should be automatically updated to reflect the default folder for this project. By default the project name will be the same as the folder in which data generated by the project will be stored.
- Ensure that the Project Folder path is an acceptable storage location
- The remaining Folder fields can remain on the default settings

By default, projects created within Pathfinder Office consist of a series of data folders automatically created by the software for use in different tasks. Within the main project folder, named according to the name specified for the project, are three standard folders named 'base', 'export' and 'backup'.

- Leave the remaining folder field names unchanged to accept the standard folder naming conventions.
- Accept the new project settings by clicking OK in the "Project Folders" dialog.

The settings you entered in the Projects Folders dialog should be reflected in the "Select Project" dialog.

- Click OK to close the "Select Project" dialog.

Additional Information:
If you have already created a project and wish to continue working in the same folder, ensure that the existing project is selected in the project name drop-down list, at the top of the "Select Project" dialog.

3. Data dictionaries

A Trimble data dictionary contains a description of features, and their attributes, relevant to a particular data collection task. A data dictionary can therefore be considered a template for data collection. This template provides the outline for data collection tasks but does not store either the positional or the spatial attribute data of features. These are stored in the Trimble GPS Rover file (Appendix B).

The data dictionary can be considered as being constructed from two elements, the features to be collected in the field, and secondly a list of attributes which describe each of these features.

Features:
Features recorded via a data dictionary can be described using either a point, line or polygon data structure. Feature descriptions can be edited to meet the project requirements and multiple features of the same type are permitted within a single dictionary definition.

Feature Attributes:
Attributes are feature specific and take the form of a series of data fields which accompany the standard GPS positional information. Fields can be designed to contain numeric or text data entries. In addition data integrity can be ensured with the implementation of drop-down selection and required fields during data assignment.

As a result of this construction, data dictionaries have the advantage of being able to provide a means of structuring data collection tasks, according to the required features of a survey and ensuring data integrity, by specifying allowable data inputs.

The data dictionary editor

The data dictionary editor utility (Figure A3.1) available within Pathfinder Office provides functionality for the creation and editing of new or existing data dictionaries.

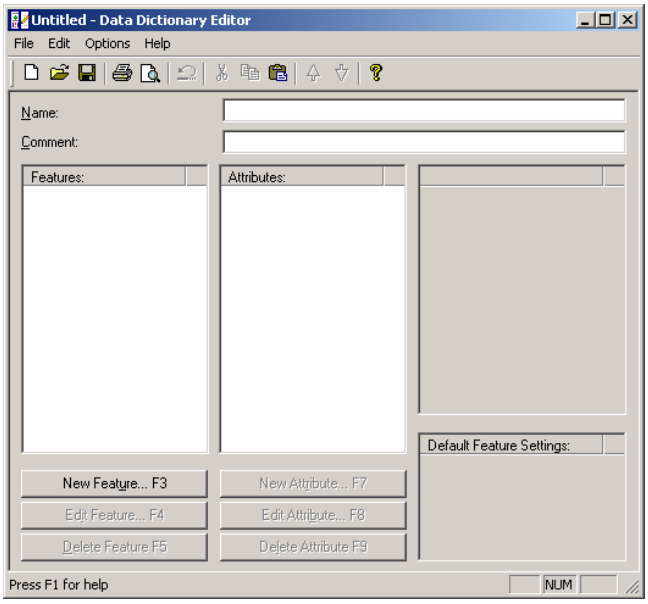


Figure A3.1 The data dictionary editor utility.

The creation of a data dictionary within this utility is based on the definition of features and their attributes.

Creating a new data dictionary

- Open the data dictionary editor by selecting “Data dictionary editor” from the “Utilities” menu in Pathfinder Office.

By default the editor will open with a blank data dictionary allowing the creation of a new definition.

- Specify a name for the dictionary at the top of the editor window

Creating a new feature

The initial step in the creation of the data dictionary structure is the creation of a new feature to which attributes can be assigned. Features can be defined as a point, line or polygon (area) depending on the type of survey and feature being recorded in the field. In the case of the current land cover and use characterisation project data will be recorded at a point, following the LUCAS survey and hence the new feature should be of this type.

- Click on the button labelled ‘New Feature’ to open the feature definition dialog (Figure A3.2).

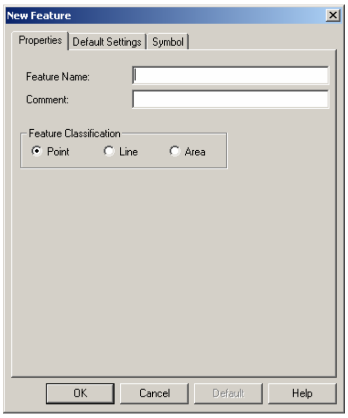


Figure A3.2 The new feature definition dialog.

- On the ‘Properties’ tab, specify a name for the feature and ensure that the appropriate feature type, i.e. point, line or polygon is selected.

The ‘Default Settings’ tab contains all the parameters relating to the type of GPS information recorded for the feature including: the GPS logging interval, minimum positions recorded and type of GPS information (code or carrier) to be collected. These parameters are survey specific and should be set to meet the data collection and accuracy requirements of the project. Within the current land use and land cover characterisation project, GPS settings of one second, code and one hundred are proposed for the logging interval, GPS data type and minimum positions, respectively.

- On the 'Default Settings' tab, specify appropriate values for the logging interval, minimum number of positions and type of GPS information to be collected.

The final 'Symbol' tab allows the specification of the symbol which will be used to symbolise the feature within the Pathfinder Office and TerraSync software.

- Click OK, to accept the parameter settings and create the feature.

On returning to the data dictionary editor window the new feature should now be included in the feature list.

- Ensure that the data dictionary definition is saved.

Adding attributes to a feature

Once a feature has been created it can be assigned a series of attribute fields. These attribute fields will be included in the data collection form, within TerraSync, for the feature.

Feature attributes are classified according to the definitions in Table A3.1. This classification influences the type and format of any information recorded in the field for that attribute.

Table A3.1 Feature attribute types.

Data Type	**Description**
Menu	Allows selection of an attribute criterion from a predefined list.
Numeric	Allow numeric value, decimal or numeric, to be entered during data collection
Text	Allow a text string to be entered during data collection
Date	Collect the date of feature creation or update, this process can be automated.
Time	Collect the time of feature creation or update, this process can be automated.
Filename	Allows the entry of a filename. This attribute type is not supported by the GeoXT or GeoXM units.
Separator	Separators can be added into the attribute list at any point. They do not represent an attribute for data collection but allow data attributes to be broken up into sections to improve readability.

The dialog used to create new attributes will vary according to the attribute type selected as the parameters required for attribute definition are attribute specific. This manual will concentrate on the creation of the 'menu attribute' type as this is the main attribute type used in the land cover and use characterisation dictionary. Further details on the creation of the remaining attributes can be found in the Pathfinder Office help.

- Attributes are assigned to the feature selected in the 'Feature List' of the "Data dictionary" dialog (Figure A3.1). Ensure that the feature created in the previous steps is selected (indicated by a blue highlight), from this list, by clicking on it.
- Click the button labelled 'New Attribute' The "New Attribute Type" dialog will automatically be opened (Figure A3.3).

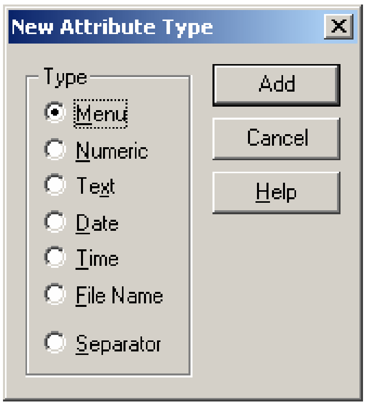


Figure A3.3 The new attribute type selection dialog

- Ensure that the 'Menu' attribute type is selected and click 'Add'. This will automatically open the new menu attribute dialog (Figure A3.4).

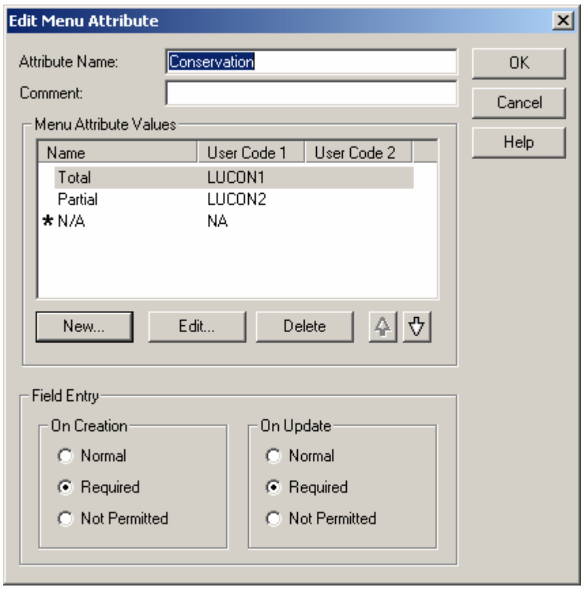


Figure A3.4 The new/edit menu attribute dialog.

The "New Menu Attribute" dialog allows the specification of the criterion which will appear in the attribute drop-down list. These criteria can be represented via a text descriptor in addition to a coded value. During data collection the surveyor will be presented with a drop-down menu based on the text descriptors however the coded values will be transcribed to the file and can be extracted during data export.

The criteria for the menu attribute values are added via the ‘New Menu Item’ dialog which is accessed via the ‘New’ button (Figure A3.4). Criteria parameters entered in this dialog include the text descriptor and up to two coded values. As criteria are added they are included in the ‘Menu Attribute Value’ list, in the order they will appear in the drop down menu (Figure A3.4). The default attribute value is indicated, in this list, with an asterisk (*). This default value is specified via a check box in the ‘New Menu Item’ dialog.

- Specify a name for the new attribute using the text box at the top of the ‘Edit Menu Attribute’dialog. This name should be unique and not contain more than 20 characters.
- Click ‘New’ to add a menu item to the current attribute.
- Complete the text descriptor and coded value fields for the first menu item. Note that the text descriptor and coded value are limited to 20 and 6 characters, respectively. Click ‘Add’ to accept these parameters and create the menu item. Repeat this process until all attribute criteria, menu items, have been entered, ensuring that the ‘Default’ checkbox is selected for the appropriate criteria.

A final requirement of the attribute definition is to specify whether the attribute is a required field. If an attribute is defined as a required field, a value must be specified for this parameter during data collection. Alternatively the attribute can be defined as normal, data entry is optional or ‘not-permitted’, or data entry is not permitted. The latter option is used in cases where the attribute is automatically generated. This is repeated both on creation, i.e. when the feature is first created and on update, i.e. if the feature is later modified.

- At the base of the ‘Edit Menu Attribute’ dialog specify whether the attribute is a required field, on creation and update, using the radio buttons.
- Finally click OK to accept the new attribute definition.

Within a data dictionary, features can have multiple attributes therefore the attribute definition process can be repeated to create further attributes.

Feature and attribute editing

Existing features and attributes can be edited or modified. Edit dialogs are accessed via the appropriate ‘Edit’ button, ensuring that the feature or attribute for modification is selected. Edit dialogs are equivalent to the new dialogs previously outlined.

Data dictionary structure Import.

An alternative to the manual definition of the data dictionary within the editor, as outlined previously, is the automated import of the dictionary structure. This structure can be imported from an existing TerraSync rover file or ASCII format file. As import from a TerraSync rover file would primarily form the basis of data dictionary modification, this manual will concentrate on ASCII import as a means of new dictionary definition.

To enable import from an ASCII (*.txt) format, the file must be constructed in the appropriate format, as expected by the Pathfinder software. Figure A3.5 illustrates this structure via the data model and based on an example dataset.

Data model:

```
Dictionary
Feature 1(Point, Line or Area)
        Attribute 1(Menu, Numeric, Char, Date, Time)
                (Attribute value 1)
                (Attribute value 2)
                        .
                        .
                (Attibure value n)
        Attribute 2
                        .
                        .
        Attribute n
Feature 2
        .
        .
Feature n
```

Example data:

```
"Landuse", Dictionary, "Land use characterisation dictionary"
"Sample point", point
        "Conservation", menu, required, required
                "Total", [LUCON1]
                "Partial", [LUCON2]
                "N/A", [NA], default
        "Collection", menu, required, required
                "Plant products", [LUCOL1]
                "Animal products",[LUCOL2]
                "N/A", [NA], default
```

Figure A3.5. The data dictionary structure within an ASCII format file for definition import

The example dataset is that used in the creation of the land use characterisation data dictionary associated with this report. This data dictionary concentrates on the creation of menus for each attribute which are populated with text descriptors and associated code values. Specification of attribute menus requires the format and data information as outlined in Figure A3.6.

Dictionary
Feature 1(Point, Line or Area)
    Attribute 1, menu, 'On creation', 'On update'
        "Menu item 1 – text", [code value 1], *(default)*

Where;

- 'On creation' or 'on update' should be specified as either 'Normal' or 'Required'

The normal keyword indicates that a value can be entered for this attribute but the user is not forced to do so. Required indicates that a value must be entered for this attribute.

- Code values should always be enclosed by square brackets
- The default keyword indicates that the specified menu item is the default value for the attribute

Figure A3.6 ASCII file construction for definition of a menu attribute

The data dictionary structure, as specified, should be created and edited within a simple text editor and saved with the extension *.txt.
It should be noted that rules concerning feature and attribute naming (section 2) are still applicable within this method of data dictionary creation and therefore should be adhered to within the ASCII file construction.

- Within Pathfinder Office, open the 'Data Dictionary Editor' from the 'Utilities' menu.
- Select 'Import from ASCII file' from the 'File' menu. Within the subsequent dialog browse to the appropriate ASCII file. Click 'Open'.

The data dictionary editor will now contain the new dictionary structured as specified in the ASCII file. This data dictionary should be saved and subsequently modified using the standard utility tools as appropriate.

Appendix B

Appendix B

Land Cover and Land Use Survey:

TerraSync and Data Dictionary Operation Manual

1. Introduction

This manual outlines the GPS (Global Positioning System) operation for implementation of a land cover and land use survey, based on the supplied data dictionary for data input. The manual will focus on implementation of the data dictionary within the TerraSync software, on a Trimble GeoXT or GeoXM device, including field preparation, data collection and results collation.

Software and Hardware requirements

The following components are required to follow the manual:

- Trimble TerraSync Professional installed on a Trimble GeoXT/XM GPS receiver
- Trimble Pathfinder Office and Microsoft ActiveSync installed on a Windows PC

What is TerraSync?

The TerraSync software is designed to allow the collection of GPS and field survey information. The software can be installed on both Windows CE devices, with or without, integrated GPS or on a standard PC.
If installed on a device with an integrated GPS using TerraSync it is possible to monitor GPS status, set GPS parameters, navigate to preset coordinates and collect and update feature data.

This manual will concentrate on the implementation of a field survey, using TerraSync Professional Edition. It should be noted that a scaled down version of this TerraSync product, TerraSync Standard Edition, is also available which imposes restrictions on functionality. For example, the standard edition does not support the display of raster maps or images in the map section, covered in section 4.

TerraSync Layout.

TerraSync is arranged into 5 sections, one of which is always visible (Figure B1.1). The visible section is controlled by the section list drop-down located in the top left-hand corner of the TerraSync window. The active section is that section visible when the drop-down is contracted.

- Map
- Navigation
- Data
- Status
- Setup

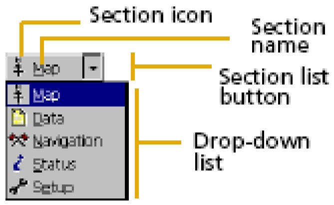


Figure B1.1 TerraSync sections and their selection. The "Map" section is the currently active view (Adapted from Trimble 2006).

Sections Introduction

Map

The map section is primarily used to aid navigation in the field although it can also aid in field interpretation and surveying. The map section allows the user to view features within the current data file in addition to any pre-loaded raster or vector background maps of the study area.

Navigation

This section enables the user to navigate from their current location to a pre-defined location. Information included in the navigation window includes the distance left to travel, bearing of shortest path and current heading. The direction of travel, to achieve the shortest path, between the current and target position is also indicated in the form of a direction dial.

Data

This is the primary section used in data collection, editing and updating for both positional and attribute information.

Status

The status section allows the user to monitor, the current location and health of GPS satellites being tracked by the unit in addition to the current status of both the software and data collection

Setup

The setup section is split into several sections which allow the parameters determining the behaviour of the software, data collection and GPS interaction between the unit and GPS satellites to be specified.

Sections and Subsections

Several of the TerraSync sections, outlined in the previous discussion, have a series of subsection elements. These subsections are section dependent and allow further control of the TerraSync software. Subsections are selected using the secondary drop-down typically found in the top left of the TerraSync window (Figure B1.2).

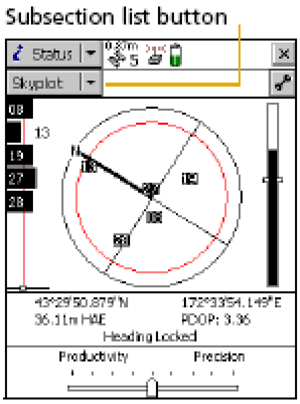


Figure B1.2 Identification of the subsection list button and drop-down menu (Trimble 2006).

If the current section being viewed has subsections then the subsection list button will automatically be available. Moving between subsections is possible at anytime although some subsections may be unavailable depending on the current task.

2. Preparing for data collection

Prior to data collection the Pathfinder Office software will be used to transfer the land cover, land use data dictionary and raster background maps to the GPS unit. Pathfinder Office is the PC based software that accompanies Trimble GPS units (needs to be purchased separately). This software provides tools which enable user to plan GPS surveys and successfully download and process the resultant data.

Creating a Pathfinder project

The Pathfinder Office software is based on the concept of projects. Whenever the software is in use the processing tasks must be completed within a project. These projects represent a good way of organising your data, for example similar files from a survey area or date, can be grouped.

Initially you will create a new Pathfinder project in which to conduct the PC based work for the survey.

- Open Pathfinder Office from the Start Menu or desktop icon

On opening Pathfinder Office the “Select Project” window should open automatically, if it does not open then select *File/Projects*.

From the “Select Project” dialog you can open an existing project, if a suitable project for your current work has been created, or create a new project.

To create a new project,

- Click ‘New’ at the base of the dialog to open the “Project Folders” dialog.

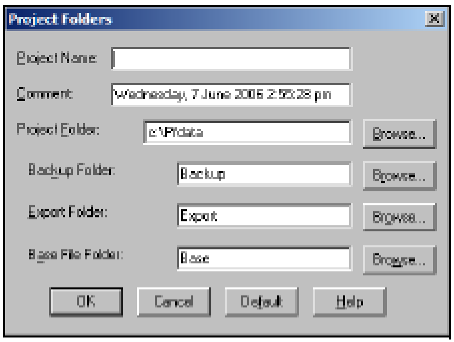


Figure B2.1 The Create new project dialog

- Specify a Project Name. A series of invalid characters exist when specifying this name these include characters such as +, >, ? and “
- Press Enter or click away from the input field to accept the new project name. The Project Folder field should be automatically updated to reflect the default folder for this project. By default the project name will be the same of the folder in which data generated by the project will be stored.
- Ensure that the Project Folder path is an acceptable storage location
- The remaining Folder fields can remain on the default settings

By default projects created within Pathfinder Office consist of a series of data folders automatically created by the software for use in different tasks. Within the main project folder, named according to the name specified for the project, are three standard folders named ‘base’, ‘export’ and ‘backup’.

- Leave the remaining folder field names unchanged to accept the standard folder naming conventions.
- Accept the new project settings by clicking OK in the “Project Folders” dialog.

The settings you entered in the “Projects Folders” dialog should be reflected in the “Select Project” dialog.

- Click OK to close the “Select Project” dialog.

Additional Information:
If you have already created a project and wish to continue working in the same folder, ensure that the existing project is selected in the project name drop-down list, at the top of the “Select Project” dialog.

Connecting the GPS unit to the PC

The following tasks require the transfer of files between the PC, Pathfinder software, and the GPS unit therefore before continuing you must ensure that the GPS is connected to the PC.
Please note that connection between the GeoXT, which is a Windows CE device, and the desktop PC is enabled by Microsoft ActiveSync. This software, which is freely available for download from the Microsoft website, must be installed on the desktop PC.

- Ensure that the cabling and docking station are connected.
  The GeoXT connects to the desktop PC via a USB cradle connection. Ensure that the USB lead is plugged into both the docking cradle and USB connection on the PC. Note that the cradle does not need to be plugged into an electrical socket for data transfer this is only a requirement if the GPS device requires charging.
- Ensure that the GPS device is seated properly in cradle
- ActiveSync should automatically prompt the user for connection settings.

Connection can take the form of a partnership or guest connection. For details on the most appropriate connection consult the Microsoft ActiveSync help.

Once a connection is established the ActiveSync desktop icon should become enabled and show as green in colour.

File Transfer

Prior to the field survey the surveyor should ensure that the data dictionary, sample point locations and any required background maps are stored on the GPS device.

The land cover and land use data dictionary

A data dictionary is a description of features, and their attributes, relevant to a particular data collection task. In essence a data dictionary is a template for data collection. This template provides the outline for data collection tasks but does not store either the positional or attribute data of features. Data dictionaries therefore provide a means of structuring data collection tasks, according to the required features of a survey, and ensuring data integrity, by limiting data input.

Background maps

Background maps will be displayed in the map section of the TerraSync software to aid navigation and field interpretation. These maps may be in a raster or vector format, examples include aerial photography or satellite imagery of the area, or vector format, examples include ESRI shapefile data containing river or road networks.

Prior to transfer, format conversion and processing of these data may be required.

Raster data
Raster data should be stored in either a bitmap (.bmp), JPEG (.jpg), MrSID (.sid) or TIFF (.tif) format. To enable these raster data to be displayed in the correct geographical location within the map section they should be accompanied by a world (.wld) file, which tells TerraSync how the pixels sit and relate to each other in geographical space, and a coordinate system file. This georeferencing information is easily created in a standard GIS package.

Vector data
Supported vector file formats are AutoCAD (.DXF), ESRI Shapefile (.shp) and MapInfo (.mif). To be displayed correctly the vector data should be georeferenced. An additional processing step is required in the case of vector data prior to display. This step, carried out using the import utility, is required to convert the vector file into a Trimble data file format (.imp).

- Ensure that the vector data is georeferenced and available on the desktop PC
- Within the current Pathfinder Office project open the import utility from the main menu, *Utilities/Import* or by using the shortcut on the Utilities toolbar 

  The “Import” utility dialog should appear similar to Figure B2.2

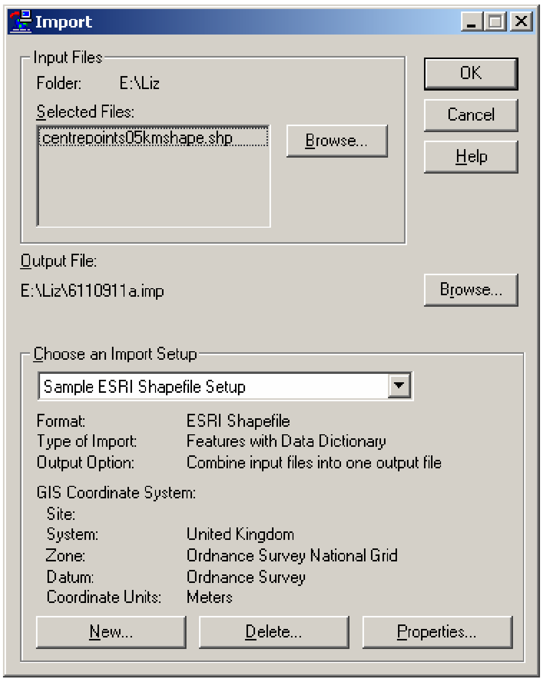


Figure B2.2 The "Import" utility dialog.

- To select the files for import click the 'Browse' button within the "Input Files" section of the dialog.
- Navigate to and select the appropriate vector file in the "Select GIS Data Files" dialog. Click 'Open' to accept the selected file and close the dialog.
- The selected file for input should now be listed in the selected file portion of the "Import" dialog.

By default the output file will be given an alphanumeric name and stored within the project folder. It is recommended that the default name is changed to ensure a more descriptive and appropriate file name.

- Click the 'Browse' button adjacent to the output file to open the "Specify Output File" dialog.
- In the "Specify Output File" dialog specify an appropriate file name for the vector data. Click 'Save' to accept this name and dismiss the dialog

While several vector data formats are supported the following instructions assume that the vector data is stored in an ESRI shapefile format and that the file is georeferenced to geographic coordinates on the WGS84 datum. Import of the other vector formats is similar, however, the setup parameters may vary. Further details can be found in the Pathfinder Office help.

- Ensure that "Sample ESRI Shapefile Setup" is selected, in the drop-down menu, under the "Choose and Import Setup" section.
- Click the button labelled "Properties" at the base of the dialog to open the import setup properties dialog.

The "Import Setup Properties" dialog contains a series of parameters controlling file import. Changing these parameters will influence the characteristics of the imported data file. For the current import, only a small number of parameters need be changed from their default values.

- In the "Import Setup Properties" dialog click the tab labelled "Coordinate system"
- The current coordinate system listed should exactly match that defined on the shapefile. If the current coordinate system is not correct click the 'Change' button. In the dialog which opens set the coordinate system to "Latitude/Longitude" and datum to "WGS 1984" Click OK to accept the new system.
- The remainder of the import settings can be left at the default settings. Click 'OK' to dismiss the "Import Setup Properties" dialog.
  The properties set should now be reflected in the main import dialog.

- Click 'OK' to proceed with the import
  The progress of the import will be displayed in a status bar window.
- When import is complete dismiss the summary window by clicking 'Close'.

Data transfer

Once the raster image(s), data dictionary and imported vector file(s) have been collated on the desktop PC they can be transferred to the GPS unit using the data transfer module of the Pathfinder software.

- The Data Transfer module is opened from the main menu, *Utilities/Data transfer* or by using the shortcut on the 'Utilities' toolbar 

If you have not previously used the data transfer utility then the 'Device' section of the dialog will be greyed out. In this case a new device must be specified to allow connection to the GeoXT via the Pathfinder Office software.

- Click the button labelled "Devices…" to open the "Devices" dialog.
- At the base of the "Devices" dialog click "New…"
- In the "Create New Device" window select "GIS Datalogger on Windows CE" from the list of available devices
- Click OK to close the "Create New Device" dialog
- The "GIS Datalogger on Windows CE" should now be listed in the "Devices" dialog. Click "Close" to close this dialog and return to the "Data Transfer" dialog.

On returning to the "Data Transfer" dialog the "GIS Datalogger on Windows CE" should be listed in the Device dropdown menu and the dialog should now be active.

If Pathfinder Office has been able to connect to the GeoXT the dialog will show that the device is connected (Figure B2.3). If connection has not been successful the user may have to search again for the device by clicking on the "Connect" button.

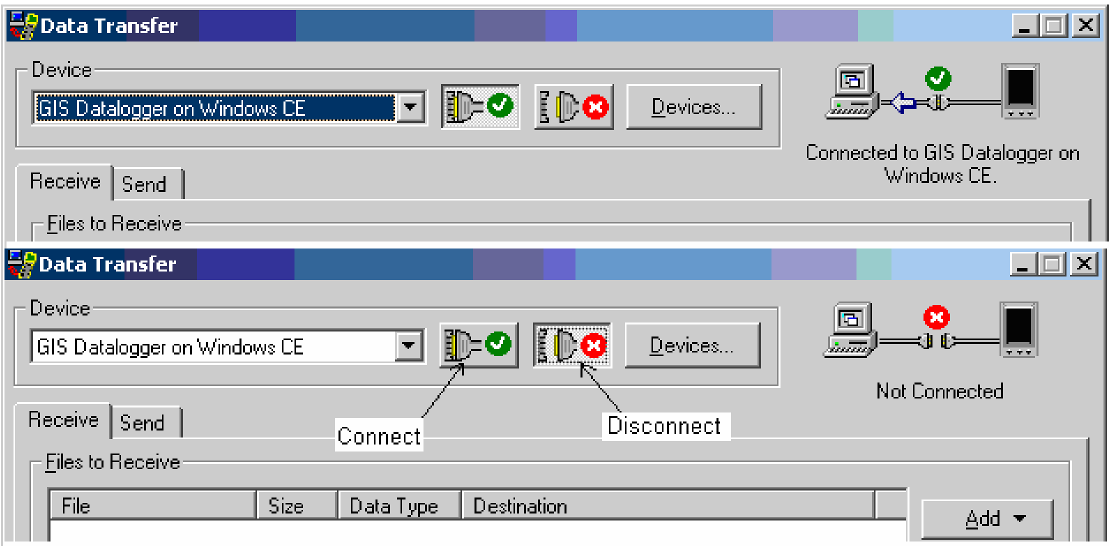


Figure B2.3. Illustration of the "Data transfer" dialog after successful (top image) and unsuccessful (bottom image) connection to a device.

If a connection cannot be established after re-clicking the connection button check all cabling and ensure that the ActiveSync guest or partnership connection is properly established.

Once a successful connection has been established the data dictionary and raster maps can be transferred.

- In the "Data Transfer" dialog select the 'Send' tab to enable transfer of data to the device.
- Once the 'Send' tab is selected, click the 'Add' drop-down menu

Specifying the data dictionary

- Select "Data dictionary" from the 'Add' drop-down menu
- In the "Open" dialog which opens automatically browse to and select the survey data dictionary
- Click 'Open'

The data dictionary file should now be listed in the file transfer dialog

Specifying the raster images

- Select 'Background' from the 'Add' drop-down menu
- In the "Open" dialog browse to and select the appropriate raster image(s)
- Click 'Open'
  The raster image file(s) should now be listed in the "File Transfer" dialog

Specifying the imported vector files

- Select 'Data File' from the 'Add' drop-down menu
- In the "Open" dialog browse to and select the imported vector file (.imp)

- Click ‘Open’
  The vector file(s) should now be listed in the “File Transfer” dialog

Transferring the files

- Click ‘Transfer All’ to complete the transfer process.

During data transfer a progress bar will be displayed showing the progress on the task. Once file transfer is complete a file transfer completed message will be displayed.

- Dismiss the transfer complete message by clicking close

During transfer a log file (.txt) is created in the project folder. Should transfer be unsuccessful it is recommended that this file is opened, from either the transfer failed window or “My Computer”. Inspection of this file is recommended to determine why transfer was unsuccessful.

Survey point locations

As the survey point locations are all predetermined according to the sampling scheme, these data can be transferred onto the GPS unit to aid navigation.
The following steps assume that the survey point locations are held in a georeferenced shapefile, projected to the same coordinate system as the raster image files.

Two methodologies can be followed for the transfer and display of these survey locations. The first methodology uses the same approach as the vector background files in which the shapefile is converted to a Trimble format, via the import function in Pathfinder Office, prior to transfer to the unit. Alternatively, the shapefile can be transferred to the GPS device in its current format, conversion to a Trimble data file format is then achieved within the TerraSync software. To allow further exploration of the function of TerraSync the second methodology will be outlined.

As Pathfinder Office does not support the transfer of shapefiles to the GPS device, via the data transfer utility, the shapefile must be transferred to the device using the standard “My Computer” tools.

- Ensure that the GPS device is connected to the desktop PC via ActiveSync
- Open “My Computer” on the desktop PC
- Navigate to the survey point location shapefile, use the ‘Copy’ tool to place this shapefile onto the clipboard.
  Note: A shapefile is not a single file when viewed in “My Computer”. Instead the file will consistent of multiple files, each with the same file name but varying extensions (.shp, .shx, .prj, .dbf).
  Ensure all file elements are placed onto the clipboard.
- Navigate to the Mobile Device (GPS unit) in the “My Computer” dialog of the desktop PC. As the devices are connected via ActiveSync you should be able to paste the shapefile into an appropriate folder on the mobile device.
  If you cannot see the drives of the mobile device from the desktop PC check the docking cradle cabling and ActiveSync connection.

Project Planning

A further utility of the Pathfnder software is a project planning tool which is designed to aid the scheduling of GPS field sessions. This Quick Plan extension or utility allows prediction of satellite availability at each survey location and determination of the best survey periods based on required PDOP and number of satellites constraints.

The Quick Plan utility is based on the GPS satellite almanac. The almanac data set contains time and position information for each GPS satellite orbit. An almanac typically contains predicted satellite orbit information over, approximately, a calendar month.

To ensure reasonably accurate results the Quick Plan utility requires a current almanac. If the desktop PC does not have an almanac or the current almanac is out of date it is important to obtain a current version prior to using the utility. Up-to-date almanacs can be downloaded from two locations. Firstly the file can be downloaded from a GPS receiver or datalogger and secondly if a GPS unit is not available a current file can be downloaded from the Trimble internet site (www.trimble.com).

Updating the Almanac

Prior to downloading the current Almanac from the GPS datalogger it is important to ensure that the device contains an up-to-date file.

- Outside, in an area of relatively open sky, turn on the GeoXT unit.
- Start the TerraSync software from the start menu, desktop icon or inbuilt GPS shortcut, F1, if available.

More information on TerraSync and its operation will be given in later sections of this manual. The following instructions cover only how to determine the currency of the almanac.

- Using the drop-down menus in the top left hand corner navigate to the “Sat Info” subsection of the Status screen by ensuring the top menu has status listed and “Sat info” is selected from the bottom menu as illustrated in Figure B2.4

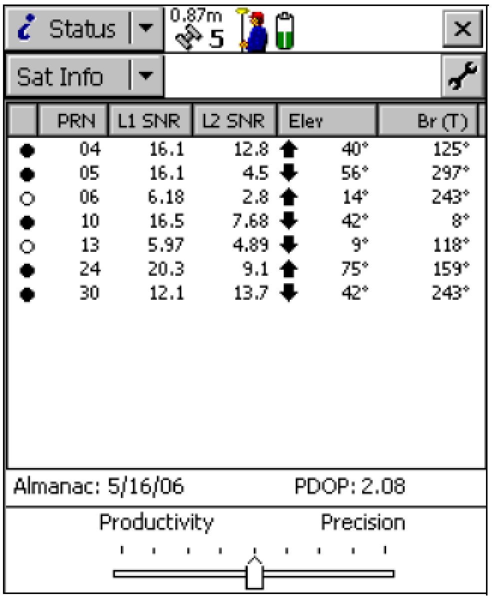


Figure B2.4 The satellite information window as a means to check almanac currency (Trimble, 2006)

The TerraSync window should appear similar to that in Figure B2.4, please note that there will be some variation as the satellites being tracked will differ as will the GPS settings in the status bar.

The date of the almanac, last received by the device, is listed towards the bottom left of the dialog, for example, 16th May 2006 in Figure B2.4. If the date is not current (within a month) or is replaced with a question mark (?) there is no current almanac. In this case ensure a clear sky view and allow time for the device to receive satellite broadcasts containing the new almanac. Once a new almanac is received a small message will appear in the status bar (at the top of the display).

Downloading the almanac

After ensuring a current almanac is available on the device this can be downloaded to the desktop PC.

If Pathfinder Office was closed after data transfer the following tasks are required to re-open the existing project.

- Open Pathfinder Office.

Almanac transfer must take place within a Pathfinder Office project. As a project was previously created, to transfer data files to the device, this project will be used for almanac transfer.

- On opening Pathfinder Office the “Select Project” window will open by default. If it does not open then select *File/Projects*.

In this dialog you can open an existing project, if a suitable project for your current work has been created, or create a new project. In this case the project created prior to field survey will be re-opened.

- In the “Select Project “window ensure that the name of the project you created prior to field survey is selected in the project name drop-down list
- Click OK to close the “Select Project” dialog.

To download the almanac from the GPS device,

- Ensure a USB connection is established between the GPS and desktop PC using ActiveSync
- In Pathfinder Office open the data transfer utility from the main menu, *Utilities/Data transfer* or by using the shortcut on the Utilities toolbar 

In the "Data Transfer" dialog ensure "GIS Datalogger on Windows CE" is the listed device within the "Device" dropdown menu.

If Pathfinder Office has been able to connect to the GeoXT the dialog will show that the device is connected (Figure B2.3). If connection has not been successful the user may have to search again for the device by clicking on the 'Connect' button.

If a successful connection cannot be established after re-clicking the connection button check all cabling and ensure that the ActiveSync guest or partnership connection is properly established.

Once a successful connection has been established the almanac can be transferred.

- In the "Data Transfer" dialog select the "Receive" tab to enable transfer of data from the device.
- Once the "Receive" tab is selected, click the 'Add' drop-down menu, select 'Almanac'.
- The "Data Transfer" window will automatically open requesting the output location and file name for the transferred file. Leave these settings at the default values.
- Click 'OK'
  The almanac should now be listed in the files to receive section of the "Data Transfer" window.
- Click 'Transfer All' to initialise the transfer
- Click 'Close' to dismiss the "Transfer Complete" message.
- Close the "Data Transfer" utility and return to the main Pathfinder Office window.

Quick Planning

- Open the "Quick Plan" tool using either the main menu, *Utilities/Quick Plan* or toolbar icon 

On opening the "Quick Plan" tool a wizard will automatically open to aid setup of the survey parameters.

- When prompted select the appropriate date for which the survey is planned.
- Click 'OK' to accept the date.

The wizard will automatically open the "Edit Point" dialog box. The "Edit Point" dialog allows selection or definition of a point at which GPS observations are planned. Quick Plan will calculate satellite visibility from the location.

Points can be selected by clicking on a world map, selecting a city from a predefined list or manual keyboard entry. As the survey location coordinate is precisely known the following instructions illustrate keyboard entry for point creation.

- Click ‘Keyboard’ in the “Edit Point” dialog

For point definition a name, latitude and longitude coordinates must be specified, other data entry fields are optional.

- Enter an appropriate name in the “Station Identification” section of the dialog. This may be, for example, the sample point identification number.
- Click inside the latitude input box. Specify the latitude of the survey location ensuring that the coordinate is given in degrees, minutes and seconds with each element being placed in the appropriate box.
- Specify whether the latitude coordinate is North (N) or South (S) using the radio button adjacent to the coordinate.
- Repeat for the longitude coordinate.

If further information about the survey location is known it can be entered into the remaining fields or they can be left as default, empty values.

- Click ‘OK’ to accept the changes and return to the “Edit Point” dialog.
- The coordinate and name information specified for the point should be listed in the “Edit Point” dialog.
- Click ‘OK’ to create the point

The Quick Plan utility automatically displays the status dialog outlining the parameters for the current session. Now that a point has been created and a survey date specified, information on the number and geometry of satellites at the point on the specified date can be visualised.

- From the main menu in the Quick Plan window select “Graphs/Number SVs and PDOP”.

A graph should be created in the main window which plots the number of satellites and PDOP against time. The time axis represents the survey date selected split into 4 hour sections. Within the graph, Quick Plan uses colour to distinguish different types of information, for example, magenta is used to indicate greater than 11 satellites while red indicates less than 4 with a gradation of colours in between.

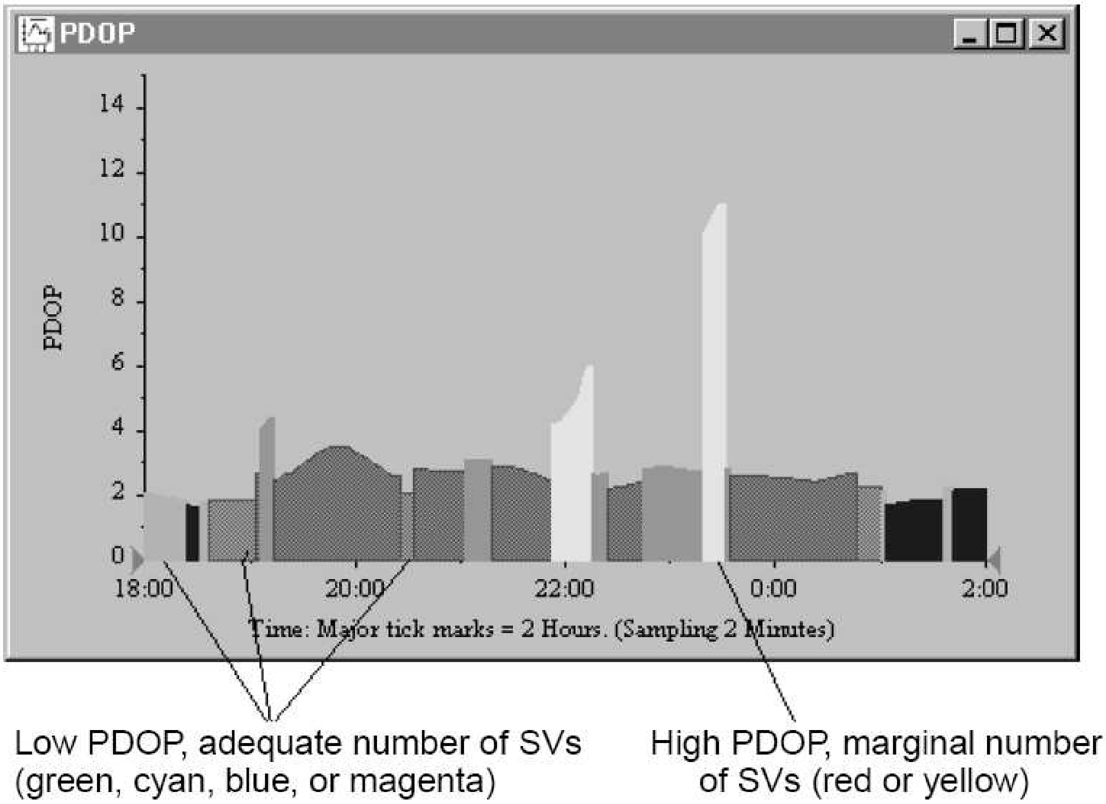


Figure B2.5. Interpretation of the Quick Plan PDOP graph

Using the graph it is possible to identify periods during the day when the number of satellites visible or satellite geometry at the survey location will be poor (i.e. PDOP high, number of satellites low, indicated by yellow or red bars). The identified time periods should be avoided for field survey. Figure B2.5 indicates how to interpret the graph.

The Quick Plan utility has a variety of further graphical display and parameter settings which can be used to further refine survey planning however, these tools are too numerous to outline in this document. For further information, the reader is directed to the Quick Plan help file or Pathfinder Office documentation.

- Exit the Quick Plan utility (*File/Exit*).

3. GPS Setup and Initial Tasks

The remaining sections of the manual illustrate how the GPS can be utilised to navigate to sample points and record land use and land cover using a data dictionary. Prior to using these tools, initial tasks should be completed to initialise the GPS receiver.

Initial tasks

Tasks which should be completed once in the field, prior to data collection are:

- Opening Terrasync
- Check the GPS status and ensure a clear sky view

Opening TerraSync

TerraSync is available from the start menu of the device on which it is installed. Additional shortcuts to the software, if installed, are the desktop icon (open via a double tap) and satellite shortcut button (F1) adjacent to the GeoXT screen.
By default TerraSync will open in the "Status" section.

Checking the GPS status

Prior to checking the GPS status you must ensure that you have a clear view of the sky. GPS signals are influenced by buildings, heavy tree cover and any objects which will act to block or deflect the GPS signal. This condition is true both when starting the GPS unit and during data collection.

By default TerraSync will open on the "Status" section, if you are not currently viewing the "Status" section you should move to this section using the section drop-down.

The "Status" section contains a series of elements which indicate the current status of the GPS signals and receiver.

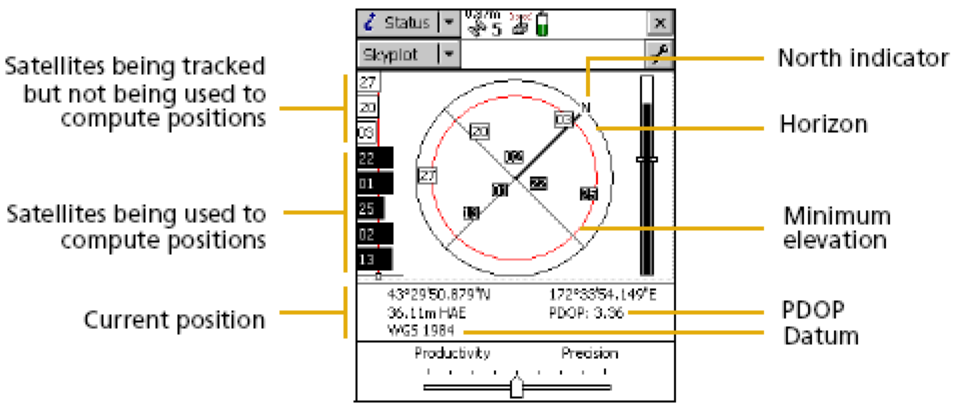


Figure B3.1 The "Status" section of TerraSync as a means of checking the GPS status

Important elements you should consider in the "Status" section are (Figure B3.1):

Satellite locations

The central diagram of the window indicates the location of the GPS satellites relative to your position and the horizon, depicted by the outer black circle. Each satellite is represented by a small numbered square; this number is unique for each satellite within the GPS constellation. If the square is filled in, black in colour, then the satellite signal is sufficiently strong and this satellite is being used to compute the current location. Alternatively unfilled or white satellites are those being tracked but not used to compute a location at the current time. The satellites being used will vary according to their location in the sky, satellites must be above the specified elevation mask (indicated by the red line). Satellites below this mask are considered too close to the horizon and therefore too prone to error in position calculation hence they are excluded.

To enable data collection you must be tracking and considering at least 4 satellites. A summary of the number of satellite with sufficiently strong signal and therefore being used to calculate the current position is included at the top of the dialog  5 indicating that 5 satellites are being used.

Please note, on initialising the GPS receiver for the first time or after a period of inactivity the unit make take a few moments to determine satellite locations and start tracking. During this time the device is receiving the current satellite almanac. The almanac is a data file, transmitted by the GPS satellites, that contains orbital information on all GPS satellites, clock corrections and atmospheric delay parameters. It is used to facilitate rapid connection to the GPS satellites.

Position dilution of precision (PDOP)

In addition to the number of satellites being tracked another important consideration is the location of these satellites in the sky. Satellites should be well distributed and relatively high in the sky, as illustrated in Figure B3.1.

These positional considerations are reflected in the PDOP measurement. The PDOP measure stated at the base of the dialog is a measure of the quality of the GPS signals based on the geometry of the satellites being used to calculate a position in the sky. When satellites are well spaced in the sky relatively to each other then the PDOP value is low and the GPS signal accuracy high.

PDOP is therefore an indication of the quality of the GPS signal being received, the lower the PDOP the better the accuracy of any location measurements.

Battery status

The battery status for the device is indicated in the status bar at the top of the window. This is visible whenever TerraSync is in operation.

4. Navigation and Background Maps

Ideally the surveyor should use standard maps and knowledge of the local area to travel as close to the pre-determined survey location as possible. Once in the proximity of the survey location the GPS unit should be switched on, the TerraSync software initialised and the initial tasks, outlined above, completed.

Once the GPS device is tracking sufficient satellites to compute a position the unit can be used to display images and vector data of the area and navigation tools used to refine the surveyors' location relative to the survey location.

Background maps and datasets

To aid navigation any raster background maps of the area and the survey locations can be loaded into the Map section of TerraSync.

The Map section of TerraSync

The main elements of the map section are illustrated in Figure B4.1.

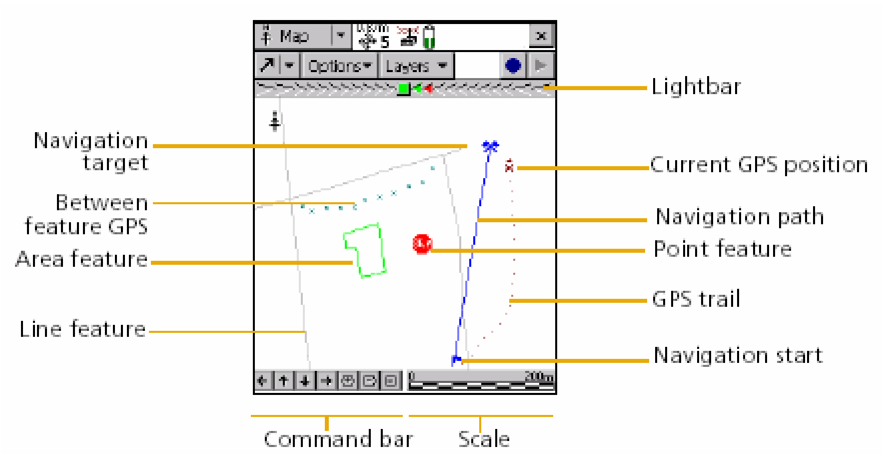
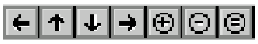
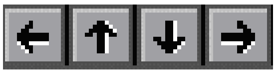


Figure B4.1 Main elements of the map section within TerraSync (Trimble 2006)

When open the Map section will illustrate features associated with the current data file, the current GPS location and the navigation start and finish locations (if set). In addition raster images and vector datasets can be added to the display.

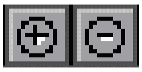
Tools for controlling the display of the Map section are located on the command bar and within the three list menus.

Command Bar Tools 
The command bar tools allow panning and zooming within the map display, enabling the user to focus on particular features.



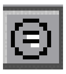
Pan tools

Pan the map half of its width (or height) in a left, right, upwards or downwards direction.



Zoom tools

Zooming tools which magnify or reduce the map scale focused on the centre of the map display



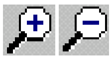
Zoom to extent

Resets the zoom factor to enable viewing of all data files within the view

Map Tools 
Further map display navigation tools are located within the map tools list menu

Select tool

Using the select tool tap on map features to select or highlight them

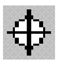


Interactive zooming tools

When these tools are selected either tap on a single point or click and drag a rectangular area to magnify or reduce the scale of the map display focused on this area.

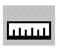
Interactive panning tool

When selected click and drag within the map display to change the focus of the map area.



Digitise tool

This tool can be used to create features within the map display



Measurement tool

The length between map features or area encompassed by a series of features within the map display can be determined using this tool.

Options List Menu 

This list menu contains items which control the map display and enable navigation. Specific tools within this menu will be considered in later report sections.

Layers List Menu 

This list menu contains tools which control the layers visible within the map display. For example, tools to control the background view are located within this list.

Setting the view coordinate system

Prior to viewing the image and vector data the appropriate coordinate system must be set on the device.

Note: The following instructions assume that the coordinate system used for the raster image and survey locations are based on the WGS84 datum. The following parameters will need to be adjusted to the map coordinate system used in your country.

- From the "Section List" menu select 'Setup'.
- In the "Setup Section", click the button labelled 'Coordinate System' to open the "Coordinate Systems Parameters" dialog.
- From the 'System' drop-down menu select "Latitude/Longitude"
- From the 'Datum' drop-down menu specify "WGS 1984"
- Set the 'Altitude Reference' to "Mean Sea Level (MSL)" and 'Altitude' units to "Meters" using the appropriate drop-down menus.

The remaining fields 'Geoid model', 'Geoid 'and 'Display USNG' can remain at the default values.

- Click 'OK' at the top of the window to accept the parameters

Note: The parameters set in the preceding steps will vary according to the coordinate system of the datasets.

Loading background raster images

- From the "Section" list menu select 'Map'.
- From the "Layers" list menu, click "Background File…" The map will be replaced with the "Background File" selection dialog (Figure B4.2).

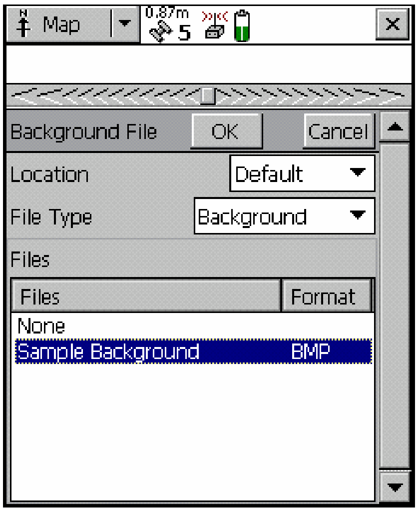


Figure B4.2 Background File selection dialog. Trimble (2006)

- Ensure the "Location" drop-down list menu is set to 'Device'.
- Set the "File Type" to 'Background' using the drop-down list

The available raster image file(s) stored on the device, should now be listed in the files section at the base of the dialog.

- Highlight the appropriate raster image for the study area in the “Files” section.
- Click ‘OK’ to return to the map display view.

Note: If the coordinate system of the raster image varies compared to that of the current map display (WGS84, set in the previous step) a warning message will be displayed and the raster not added to the map window. To resolve this issue check the projection definition in the “Setup” section.

If the coordinate systems match on returning to the map view, in addition to your current GPS location, the raster image should also be visible.

If the background image is not visible ensure that the layer visibility is enabled. The background layer is visible if the “Background” option is checked within the “Layers” list menu (Figure B4.3). By checking and un-checking this option the background layer visibility can be toggled between visible and hidden.

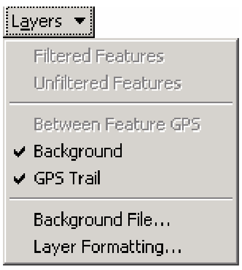


Figure B4.3 Background layer visibility

Loading background vector layers

- From the “Section” list menu select ‘Map’.
- From the “Layers” list menu, click ‘Background File…’ The map will be replaced with the background file selection dialog (Figure B4.2).
- Ensure the “Location” drop-down list menu is set to ‘Device’.
- Set the “File Type” to ‘Data File’ using the drop-down list

The available data file(s), stored on the device, should now be listed in the files section at the base of the dialog.

- Highlight the appropriate imported vector file(s)
- Click ‘OK’ to return to the map display view

On returning to the map view, in addition to your current GPS location, the vector data should also be visible.

If the background layer is not visible ensure that the layer visibility is enabled. The background layer is visible if the “Background” option is checked within the layers list menu (Figure B4.3). By checking and un-checking this option the background layer visibility can be toggled between visible and hidden.

Loading the survey point locations
While the survey point locations are vector data they will not be loaded into the map view using the background layer approach. A disadvantage of viewing vector data files within the background layers of the map display is the loss of feature attributes. While the feature attributes are held in the data file the map section is designed to eliminate this information to minimise computing requirements. In the case of the survey locations the tabular data or feature attributes contain important information regarding the survey points. To ensure this information is available to the surveyor the data file will be opened within the data section of TerraSync.

Opening the survey point data file in the data section will allow attributes to be viewed by the surveyor. A disadvantage of this approach is the potential size of the resultant data file and associated attributes. If the original shapefile contains a large number of sample points the surveyor should consider splitting the file into sub-areas to limit file size.

Prior to opening the survey location data file the shapefile must be converted into a Trimble file format using the tools available within TerraSync.

- Navigate to the “Data” section of TerraSync, select ‘Data’ from the “Section” list menu
- Select ‘File Manager’ from the ”Subsection” menu
- Select ‘Read data from shape’ from the “Options” list menu to open the “Read from Shape” dialog.
-

The “Read from Shape” dialog allows the shapefile to be converted into a TerraSync data file.

- Enter an appropriate name for the TerraSync data file in the “Create data file” input box.
- Using the “From Shapefile(s) in” drop-down list menu navigate to the folder in which the survey location shapefile is stored.
  The survey location shapefile should now be listed at the base of the dialog in the “Include” section.
- At the base of the dialog, in the Include section, ensure that the check-box adjacent to the survey location shapefile is checked.
- Click ‘OK’.

A dialog will be shown which indicates that conversion is taking place.

Note: once this conversion process has been undertaken the data file will be stored on the device therefore the conversion process need not be repeated at each survey location.

- Once the conversion process is complete dismiss the “Conversion” dialog.

To open the newly imported file or pre-existing file
- Navigate to the “Data” section of TerraSync, select “Data” from the section list menu.

- Select “Existing File” from the “Subsection” menu..
- In the existing file list, using the scroll bars if necessary, locate the TerraSync data file you just created, containing the survey locations. Select this file using a single tap or click.
- Click ‘Open’.

The survey location data file is now open, TerraSync will automatically move to the ”Update feature” form. During the survey you do not wish to update these features as they will be used solely for navigation therefore you should navigate away from the “Data” section of TerraSync.

- Navigate to the “Map” section of TerraSync, select “Map” from the “Section” list menu

The survey point locations should now be visible within the map composition.

Navigation

Navigating to the survey location will involve both the map and navigation sections of the TerraSync software. Navigation targets (the survey point) will be set within the map section while the navigation section will inform the surveyor of the shortest path to the target location.

The Navigation section of TerraSync
By default the navigation section of TerraSync, when a target is set, will appear as shown in Figure B4.4.

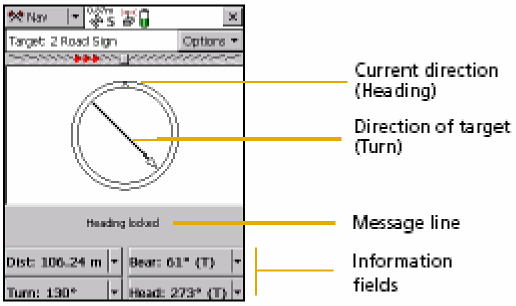


Figure B4.4 The navigation section of TerraSync, with a target set. (Trimble 2006)

The main element of this window, when navigating to a target, is the direction dial which is located centrally in the window. This dial indicates the surveyors’ current direction of travel (heading) relative to the target location. Therefore to reach the target location, using the shortest path, the surveyor should align the arrow (direction to target) with the current direction (the triangle at the top of the dial).

When using this navigation dialog there are two important elements which should be considered. Firstly, to calculate an accurate current heading and therefore required travel direction the GPS unit must be moving. If the surveyor is moving too slowly or stationary the heading arrow will appear to freeze. Secondly, the arrow indicates the shortest route to the target location, this may not be the safest or most appropriate path in terms of land use and land ownership therefore detours away from this suggested route may be required.

In addition to the navigation dial the navigation section of TerraSync is supplemented with a series of information fields which provide further details on the current heading, distance to target etc. These information fields can be replaced by a series of information fields using the drop-down option at the side of any current field.

When the surveyor approaches a specified distance from the target the navigation dial will be replaced with the close-up screen (Figure B4.5).

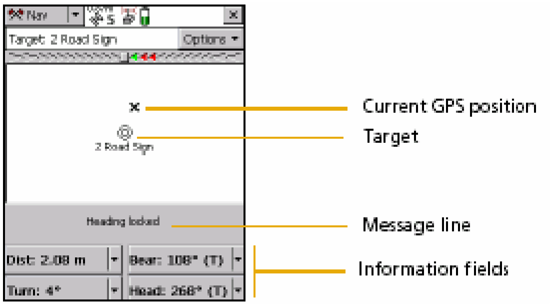


Figure B4.5: The close-up screen (Trimble 2006)

The close-up screen is designed to enable the surveyor to accurately locate the required survey location. This is achieved by aligning the current GPS position (cross) centrally on the target (circular bulls-eye). The close-up screen is aligned relative to the current heading, when the screen is first opened. This heading or alignment is not updated on the close-up screen therefore it is recommended that the surveyor travel forward, backwards and sideways, if necessary, to align the current location and target rather than turning sharply.

The close-up range, distance at which the navigation dial changes to the close-up screen, is specified within the navigation options list menu.

Setting the navigation target

- Display the “Map” section of TerraSync, select “Map” from the section list menu
- Ensure that the dataset containing the survey locations is open within the map display, as discussed above.
- Using the zoom tools, zoom in on your current location and surrounding survey locations.
- Select the “Select tool” from the map tools list menu
- Tap or click on the survey point to which you wish to navigate.
  This point should now be selected indicated by a square selection area and the feature attributes displayed on the screen.
- From the “Options” list menu select “Set Nav Target” followed by the survey point which will be identified in the menu via its unique identification number, followed by the name of the datafile i.e. *9 survey points location.*
  The navigation target symbol should be displayed over the survey point to which you wish to navigate.

Navigating to the target location

- Now that the navigation target is set move to the navigation section of TerraSync, select “Navigation” from the section list menu.
- Confirm that the navigation target is set by ensuring that the set target reads “Target: ‘*ID Survey location Point*’” at the top of the navigation window. If the display reads “Target: No Target” the target has not been set successfully, return to the map section and reset the navigation target using the previous instructions.

Prior to starting the navigation section, the close-up range should be set.

- Select “Navigation Options” from the “Options” list menu in the navigation section. The navigation dial will be replaced by the navigation options form (Figure B4.6).

Figure B4.6 The navigation options form and close-up range (Trimble 2006)

- The close-up range is specified by typing a value into the “Range” drop-down box.

The most appropriate range for use of the close-up screen is largely a function of landscape, terrain and surveyor preference. It is therefore recommended that the surveyor test various values. An initially suggested value is the default 5m. It should be noted that it is possible to disable the close-up screen by the selection of ‘None’ in the “Range” drop-down menu. This is not recommended as it may impact on the accuracy with which survey points are located.

- Set the range, in the close up portion of the dialog, to an appropriate value i.e.5m.
- Return to the navigation dial window by clicking ‘OK’ in the navigation options.

As the navigation target and options are now set the survey point can be located.

- As stated previously you must be moving to ensure an accurate heading and target direction are calculated. Start moving towards the survey location.
- As you move ensure that the arrow in the direction dial is aligned with your current heading, the triangle at the top of the dial.
- Continue travelling towards the survey location.
- At the specified range the navigation dial will be replaced by the close-up screen. Keep travelling until the current GPS location, cross and target, bulls-eye are aligned.

Please note that due to varying positional information from the GPS you may find that your current location relative to the sample point changes. As a result the “true” survey location may not be identifiable. Judgement may be required as to the location of the sample point relative to the changing GPS position.

Once you have reached the survey location you should follow any rules considering the survey, in terms of linear features, boundaries etc.

Clear navigation targets and close survey point data file
Once you have reached the survey point you are ready to record the land cover and land use information at that location. Prior to this however, it is necessary to clear the navigation targets and close the sample point locations data file.

- Return to the “Map” section of TerraSync, select ‘Map’ from the ”Sections” list menu.
- Select “Clear Nav Targets” from the “Options” list menu.
- Return to the “Data” section of TerraSync, select ‘Data’ from the “Sections” list menu.
- Ensure that you are in the “Update” subsection, select ‘Update’ from the ”Subsection” list menu.
- Click the button labelled “Close” to close the data file.
- Click “Yes” when asked if you are sure you want to close this file.

On returning to the map view the survey point locations should no longer be visible.

Please note that **closing of the survey point location file is necessary** to allow further data collection. Once data collection for the current survey point has been completed this data file can be re-opened to aid navigation to remaining survey locations.

5. Data collection

Data collection in this survey will be based on a pre-defined data dictionary. This data dictionary was transferred to the device in section 1 in this appendix.

At the first survey location a new data file should be created in which to store the feature and attribute data. At subsequent survey locations this initial file can be re-opened. Both of these tasks, in addition to data recording are achieved in the "Data" section of TerraSync.

Data file creation

- Open the "Data" section of TerraSync, select 'Data' from the "Section" list menu.
- Select "New File" from the "Subsection" list menu to open the "Create New Data File" form (Figure B5.1).

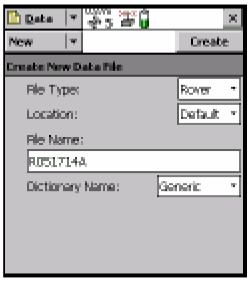


Figure B5.1 New data file creation form Trimble (2006)

In the "Create New Data File" form you must specify the file type, file name and data dictionary

File Type
Two types of data file, rover and base exist within the TerraSync software.

Rover Files
A rover file refers to a file created on a mobile GPS device. Typically the location of features recorded within this rover file are not accurately known.

Base Files
A base file differs to a rover file in that the location of the GPS device, at which data is being recorded, is known. The purpose of this base file or base station GPS is to record the derived GPS position at a known or reference location. Recorded concurrently with a rover file this information is typically used for differential correction, a process which compares the error in between the known and GPS location of the base file as a means of improving the accuracy of rover file (or unknown) GPS locations.

This survey will concentrate on the rover file type as data is recorded at a series of unknown locations. The survey locations are considered unknown because although the intended survey location is used for navigation there will inevitably be inaccuracy in the navigation target. By determining the actual GPS position a more accurate survey location is recorded.

- Ensure that rover file is specified in the “File Type” drop-down menu.

File Name
As implied the file name refers to the name of the rover file which will be created. When this section is opened TerraSync automatically generates a rover name based on the current date. It is suggested that this default file name is replaced with a more descriptive file name. The file name should meet standard Windows file naming conventions.

- Specify an appropriate file name.

Note, the filename is specified using the inbuilt character keyboard. This can be accessed from the GeoXT shortcut keys at the base of the screen display.

Data Dictionary
As stated previously, data collection will be based on a pre-defined template or data dictionary. This data dictionary should be specified when creating the new file. Once specified this association is permanently embedded within the rover file.

- Using the drop-down menu ensure that the dictionary name reflects the survey specific data dictionary file transferred to the device in section 1 of this appendix.
- Click the button labelled “Create” to finalise the settings and create the new data file.

As the new data file is created you will be prompted to confirm the antenna height. The antenna height refers to the distance between the integrated antenna on the GeoXT unit and the ground. This measurement is required to ensure accurate GPS position calculations.

- Enter the appropriate antenna height in the input box using the inbuilt keyboard. Note that antenna height should be entered in METRES.

When working with the GeoXT unit the antenna height is easily varied according to how the unit is held due to its integrated receiver construction. To try and ensure consistency it is recommended that a comfortable holding position is consistently used. Alternatively a pole or tripod of known height can be used to support the device.

Once the antenna height is specified the “Collect data” form will automatically open.

GPS settings

This manual will not provide an exhaustive description of all GPS parameters and settings available within the TerraSync software. A limited number of parameters will be considered as setting these parameters is required for data collection. Additional parameters are set within the data dictionary, these parameters will be loaded by default and hence the surveyor need not consider these parameters in the field. More details on these parameters is available in the data dictionary portion of the manual.

GPS parameters are set after data file creation to ensure that the parameters are stored within the file. As a result, GPS parameters are file specific. However, when a file is re-opened the originally specified parameters will be preset.

Logging Settings
Many of the logging settings are pre-defined in the data dictionary hence only one parameter will be considered here.

- With the data file still open, move to the "Setup" section of TerraSync, select 'Setup' on the section list menu.
- Click on the button labelled "Logging Settings".
- Ensure that the drop-down menu labelled "Confirm End Feature" is set to "Yes" (Figure B5.2).

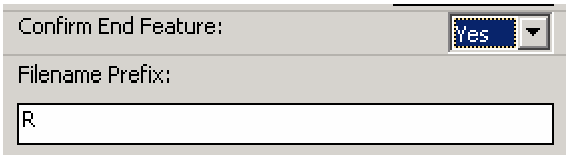


Figure B5.2 Confirm end feature, logging settings

- Leave all other menu items at the default value.
- Click 'OK' to exit the logging settings.

Real-time Settings
- Ensure you are still in the "Setup" section of TerraSync.
- Click on the button labelled "Real-time Settings".
- Ensure that "Use uncorrected GPS" is selected in the "Choice 1" drop-down menu.
- Click 'OK' to accept the changes and return to the "Setup" section.

GPS Settings
As stated previously PDOP is a measure of the quality of the GPS signal and therefore accuracy of the calculated positions. When collecting data, a limit or maximum PDOP can be set, if the PDOP reaches a value above this predefined limit data collection will stop as it is assumed the calculated positions contain too great an error.

When setting this maximum allowable PDOP value a compromise between accuracy and productivity needs to be made. If a low maximum PDOP value is specified the GPS positions recorded can be assumed to be accurate, however, productivity may be compromised as PDOP values lower than the specified will be less frequently achieved.

A recommended PDOP value is 6, the default, and a commonly used value. However, the surveyor will have to monitor the productivity implications of this PDOP value.

- Click the button labelled 'GPS settings' in the "Setup" section.
- Ensure the "DOP type" drop-down is set to 'PDOP'.

The PDOP limit or mask value can be set using either a slider or manual input. The following instructions will focus on slider input.

- Ensure the box adjacent to the slider bar is checked.
- Click on the slider bar until an appropriate PDOP value is listed in the "Max PDOP" field.
- Click 'OK' to return to the "Setup" section.

Data collection

- Ensure that the "Data Collection" form is displayed by selecting 'Data' from the section list menu and 'Collect' from the subsection list menu (Figure B5.3).

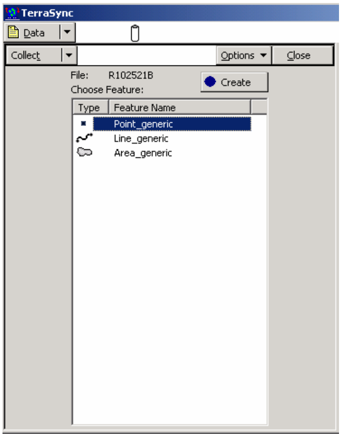


Figure B5.3 Generic data collection form

The data collection form will vary according to the data dictionary which forms the template of data collection, the form shown in Figure B5.3 is based on a generic dictionary. Characteristics common to all data collection forms, irrespective of data dictionary, are that that they contain at least one feature which is either a point, line or polygon and that they can contain multiple features and multiple feature types.

Creating a new feature

In the case of this survey the data dictionary, and therefore data collection form, contains a series of point features. These independent point features are defined to represent the land use classification and third stage of the dichotomous phase of the FAO LCCS classification,

- Cultivated and Managed Terrestrial Area(s)
- Natural and Semi-Natural Terrestrial Vegetation
- Cultivated Aquatic or Regularly Flooded Area(s)
- Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation
- Artificial Surfaces and Associated Area(s)
- Bare Area(s)
- Artificial Water bodies, Snow and Ice
- Natural Water bodies, Snow and Ice
- Land use classification

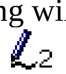
(Greyed items are not available in the current demonstration data dictionary)

Behind each of these features is a set of attributes, which are feature specific, and determine the types of data which must be recorded at the survey location.

Upon reaching the survey location, when recording the new feature position and attributes, the surveyor must initially record the land use and subsequently the LCCS information. In terms of the LCCS classification, the surveyor must determine which of the LCCS classification descriptions best describes the survey location as this will determine the point feature type created and required attribute fields.

- Locate the Land Use feature in the TerraSync data collection form. Select the point feature using a single click or tap. This point feature should be highlighted.
- Click the button labelled "Create"
  The logging position form will automatically replace the data collection window.

Whenever the maximum PDOP is below the specified value, GPS positional data is recorded for this survey location. As a result, the surveyor should stay stationary at the point and ensure that the GPS antenna remains static.

Collecting GPS positions
As stated previously as soon as the new feature is created GPS logging will commence. This is indicated by the additional logging status symbol  in the main TerraSync status bar. This symbol is accompanied by an incrementing number indicating the number of GPS positions currently recorded at the point. Ideally, to improve accuracy, a number of GPS positions should be recorded at each survey location to allow averaging in the final position determination.

The data dictionary has been constructed to ensure that at least 120 GPS positions are recorded at each survey location. These positions will be recorded at a 1 second interval whenever logging is viable.

If GPS logging is interrupted, due to GPS signal loss or PDOP values exceeding the stated maximum, the logging status symbol will cease incrementing. An additional indicator that logging has stopped is a drop in the number of satellites being tracked, this may be accompanied by an error message or a PDOP warning message.

Collecting attribute data
At each survey location the GPS positional data is accompanied by a series of attribute data fields. These attributes will vary according to the feature type selected. The attribute data fields for the current feature are displayed within the logging position form. These attribute fields are represented by a series of drop-down menus from which the most appropriate classifier can be selected.

In addition to the attribute drop-down menus a single numeric field exists for each feature. The unique survey location identification number should be entered in this field.

- Using the drop-down menus (and numeric keyboard) select an value for each of the attribute fields

Pausing GPS logging
If necessary it is possible to temporarily pause the logging of GPS positional data while at a survey location using the following steps:

- Click the button labelled "Pause"

Logging of GPS positions will now be paused allowing the surveyor to move from the survey location. A pause in logging is indicated by a flashing pause symbol in the TerraSync status bar

- To continue logging GPS positions click the button labelled "Resume"

The logging status symbol will revert back to a pencil with incrementing numbers to indicate that logging has resumed

Completing Feature Creation

When the attribute fields for the feature have been completed and sufficient GPS positional data collected the feature can be stored within the data file.

- Click 'OK' within the logging data form
- As the "Confirm end feature" parameter was set to 'Yes' prior to data collection in the GPS setup, a prompt is displayed to confirm that the user wishes to close and store the feature.
- Click 'OK' to store the feature and return to the data collection form (Note if OK has been clicked by mistake, selecting cancel will return to the logging screen)

Subsequent to the collection of land use characteristics at the sample point, the LCCS descriptors for the same location should be recorded. This is achieved via the creation of a second feature, based on the LCCS classification, at the **same sample point**.

- Based on the LCCS descriptions determine which of the dichotomous phase class descriptions best describes the survey location.
- Locate the appropriate LCCS feature in the TerraSync data collection form. Select the point feature using a single click or tap. This point feature should be highlighted.
- Click the button labelled "Create".

Data collection for this feature should proceed as described above for the land use feature. Once the attribute fields are completed and sufficient GPS positions collected, complete feature creation by clicking 'OK' on the data form and returning to the data collection form.

Closing the Data file

If logging of a second survey point is not required then the data file should be closed to allow the GPS unit to be switched off or used in a navigation mode.

- Ensure the "Data" section is visible, select 'Data' from the section list menu.
- Display the "Collection" subsection.
- Click the button labelled "Close" (Figure B5.4)

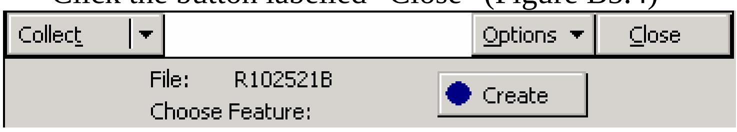


Figure B5.4 Closing the data file

- When prompted click “Yes” to close the data file

This data file is now closed and the GPS unit can be switched off or additional data sets for navigation opened.

Please note that when a further survey point is reached, a new file does not need to be created, the previous file can be re-opened as outlined below.

Opening an existing data file
If surveying multiple survey points within a given area or on a given survey day, it may be preferable to store the data in a single file, rather than creating multiple files which contain a single point.

- Open the “Data” section of TerraSync, select ‘Data’ from the “Sections” list menu.
- Select “Existing file” from the “Subsection” list menu.

The “Existing File” subsection contains a alphabetised list of existing TerraSync rover files stored on the device.

- Select the existing file to be opened from the list by single clicking on the file name. Once selected the file will become highlighted

Note that if the device contains a large number of files, the scroll bars at the side of the list can be used to find the appropriate file.

- Click the button labelled ‘Open’.

As the data file is opened a prompt is displayed to confirm the antenna height. Further details on the antenna height are given above.

- Enter the appropriate antenna height, in METRES, in the input box.
- Click ‘OK’ to confirm.

The data collection form will automatically open. This data collection form will reflect the data dictionary originally specified for the rover file.

As the GPS parameters were previously set for the data file these parameters, which are stored in the file, do not to be need to be reset therefore the surveyor is free to continue data collection.

6. Processing the Data

Following field survey the data files created should be downloaded to the desktop PC for export and processing.

This download procedure is a valuable way of backing up field data and hence is recommended on a regular basis.

Connecting the GPS unit to the PC

The following tasks require the transfer of files between the PC, Pathfinder Office software, and the GPS unit. Therefore, before continuing check that the GPS is connected to the PC.

Please note that connection between the GeoXT which is a Windows CE device and the desktop PC is enabled by Microsoft ActiveSync. This software must therefore be installed on the desktop PC.

- Ensure that the cabling and docking station are connected.
  The GeoXT connects to the desktop PC via a USB cradle connection. Ensure that the USB cable is plugged into both the docking cradle and USB connection on the PC. Note that the cradle does not need to be plugged into an electrical socket for data transfer, this is only a requirement if the device requires charging.
- Ensure that the device is seated properly in the cradle.
- Connection of the device to the PC will automatically open the ActiveSync dialog unless a partnership between the devices already exists.

Opening an existing Pathfinder Office Project

The data from TerraSync must be processed by Pathfinder Office so that the rover files can be converted initially into the Pathfinder format and finally into an export format.

- Open Pathfinder Office from the Start Menu or desktop icon

On opening Pathfinder Office the “Select Project” window will open by default. If it does not open then select *File/Projects*.

In this dialog, an existing project can be opened, if a suitable project for the current work has been created, or create a new project. In this case the project created prior to field survey will be re-opened.

- In the “Select Project “window ensure that the name of the project created prior to field survey is selected in the “Project Name” drop-down list
- Click ‘OK’ to close the “Select Project” dialog.

File Transfer

- The “Data Transfer” module is opened from the main menu, *Utilities/Data transfer* or using the shortcut on the Utilities toolbar 

As the data transfer utility has been used previously, the “GIS Datalogger on Windows CE” should be listed in the “Device” section.

- Ensure the “GIS Datalogger on Windows CE” is selected in the device window and a connection has been established.

If connection has not been successful refer to section 1 of this appendix for details on re-attempting the connection.

- In the “Data Transfer” dialog select the ‘Receive’ tab to enable transfer of data from the device.
- Once the ‘Receive’ tab is selected, click the ‘Add’ drop-down, select “Data file”.
- Locate and select the rover file in the subsequent dialog box which is opened.
- Click ‘OK’.
- The selected rover file should now appear in the “Files to receive” section of the data transfer window
- Click “Transfer All” to commence transfer.

As the data is transferred the file will be converted from a TerraSync data format to a Trimble Pathfinder Office format (.ssf). This file will automatically be stored in the current project folder.

- Upon completion, a summary dialog will be displayed and an additional text file created within the project folder which contains a summary of the transfer process.
- Click “Yes” to view the automatically generated text file or “No” to close the message dialog.

Viewing the recorded features

Prior to export, the recorded features can be displayed within the Pathfinder Office software and their properties interrogated.

- Ensure that the “Map” viewer is open in Pathfinder Office. If the map window is not visible select *View/Map* from the main menu.
- Select *File/Open* from the main menu.
- By default the “Open File” dialog box should open at the selected project folder. If not navigate to the relevant project folder.
- Select the data file transferred from the GPS, this file will have the same name as the rover file.
- Click ‘Open’.
- On returning to the map window the surveyed location features should be visible.

Information on these features can be extracted from the “Feature Properties” and “Position Properties” windows.

- Open the "Feature Properties" window by selecting *Data/Feature properties.*
- Repeat for the "Position Properties" window.
- Select a feature within the map window by clicking on the feature symbol. Feature and positional information for the selected feature will be displayed in the feature and position property windows.

Data Export

- Open the "Export" utility from the main menu *Utilities/Export* or icon located on the main toolbar 

The Export Utility
This dialog based utility is primarily designed to allow the conversion of Trimble data files (.ssf) to GIS or CAD compatible formats. When the utility opens the dialog appears similar to Figure B6.1.

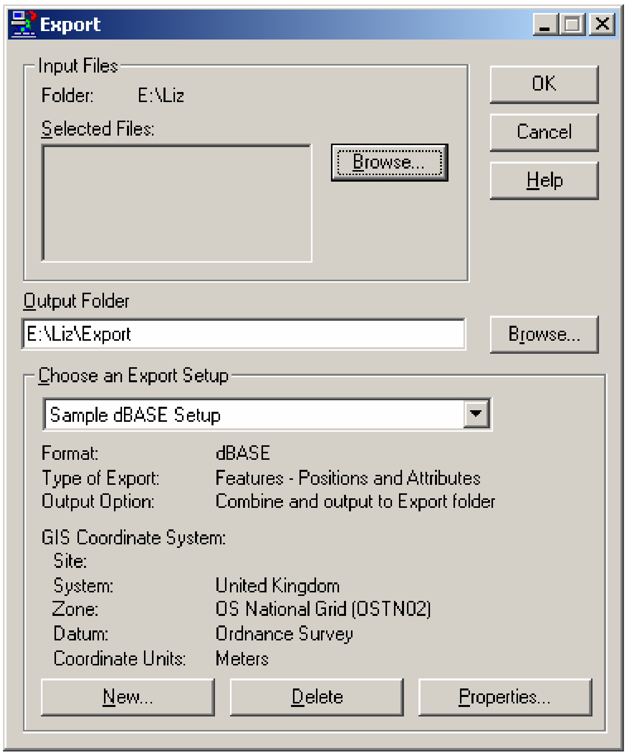


Figure B6.1 The export utility dialog

Various types of data recorded by the GPS can be exported; of importance to this project are the survey point features (positions) and their associated attributes. During the export process positions can be filtered according to pre-defined criteria.**Warning:** such a process can lead to data loss.

The export process requires the setting of a series of parameters which govern the output data type and the characteristics of the output file. Specific parameters are file type specific, however, common parameters include:

- ➢ The output file type and location
- ➢ The operating system the files are intended for

- The spatial coordinate system of the output features or their positional data
- The units of any GPS derived information i.e. length and area
- Any additional attributes derived from the GPS, referred to as generated attributes, such as PDOP and precision.

Tabular Format
One alternative is to export the Trimble data file to a table, held in a dBase format (*.dbf). In this case the spatial information will be held in the form of two X,Y coordinates within the table.

- In the "Input Files" section of the dialog ensure that the imported data file is listed in the selected file list. If the file is not listed click on the 'Browse' button, in the "Open" dialog, navigate to and open the appropriate Trimble data file.
- Ensure that the output folder is an appropriate location. By default this will be the export folder contained within the project folder.
- Using the drop-down menu set the "Export Setup" to "Sample dBASE Setup" (Figure B6.1).
- Click the button labelled 'Properties' at the base of the dialog to open the "Setup Properties" dialog.

The "Setup Properties" dialog contains all the parameters for the current export setup. Changing these parameters will influence the characteristics of the output dbase file. For the current export only a small number of parameters need to be changed from their default values.

Data Tab
- Click the 'Data' tab at the top of the dialog.
- In the 'Data' tab ensure that the "Type of data to export" is set to "Features-Positions and Attributes" using the radio button and that the drop-down menu is set to "Export All Features".

Output Tab
- Click the 'Output' tab at the top of the dialog.
- Ensure the output files is set to "Combine all input files and output to the project export folder".

Attributes Tab
- Click the 'Attributes' tab at the top of the dialog.

The 'Attributes' tab contains options regarding the generated and feature attributes. Setting these parameters will influence the fields and data contained in the exported dBase table.

- At the top of the dialog, in the "Export Menu Attributes As" section, click in the radio button adjacent to "Code Value 1" to ensure it is selected.

This is very important as the data dictionary has been constructed to allow the export of coded values. As a result each of the attribute fields in the dBase file will contain an alphanumeric code based on the recorded data instead of a text description. For example the alphanumeric code of A1 in the life form main crop field of a cultivated or managed feature is indicative of broadleaved trees.

The base of the dialog contains a series of generated attributes which can be derived, by the software, from the GPS data. These generated attributes are grouped according to feature specific categories.

- From the "All Feature Types" group of the generated attributes section, select 'PDOP', by checking the appropriate check box. As a result an additional field will be added to the dBase table which contains the average PDOP value for each feature.
- From the "Point Features" group of the generated attributes section, select 'Horizontal precision'. The generated field values give an estimate of the horizontal precision of the averaged position for each feature. This field is a distance measure, the units of which will be set in the 'Units' tab.

The line feature and area feature groups can be disregarded as neither of these feature types are relevant to the survey.

The 'Attributes' tab should appear similar to Figure B6.2.

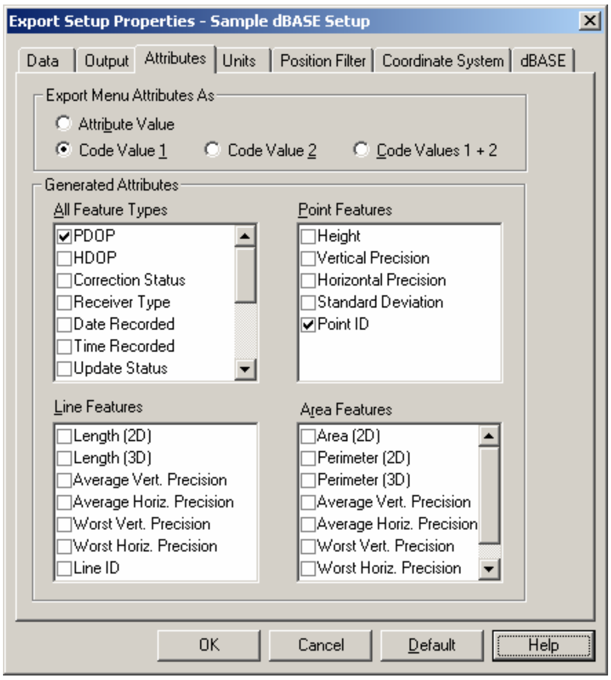


Figure B6.2 The attribute tab of the export setup dialog

Units Tab

- Click the 'Units' tab at the top of the dialog.
- Select the "Use Export Units" option.
- Ensure that the "Export Units" are set to meters, square meters and meters per second. If this not the case, click the button labelled 'Change'. In the "Select Units" dialog, which will open automatically, using the drop-down menus, select the specified measurement units. Click 'OK' to dismiss the dialog.
  The export units tab should appear similar to Figure B6.3.

Please note the distance units used in this export are a recommendation and can be changed to meet the requirements of the surveyor.

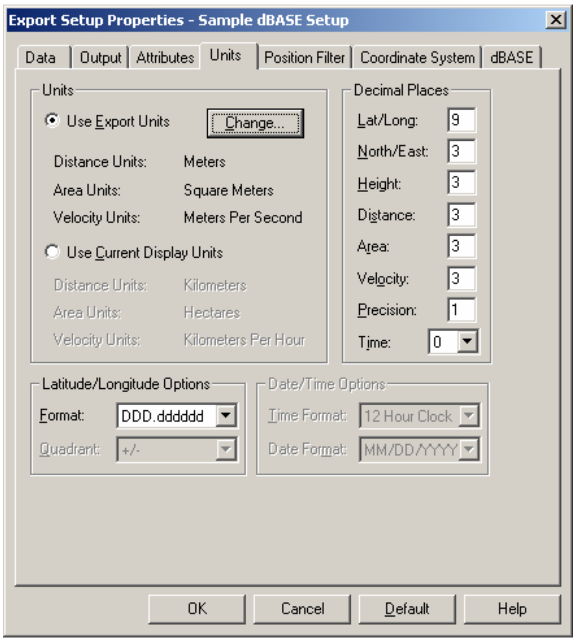


Figure B6.3 The units tab of the export setup dialog

Position Filter Tab

- Click the 'Position filter' tab at the top of the dialog

The 'Position Filter' tab contains a series of parameters to control the criteria based filtering of positions during export. Filtering can be based on a series of parameters including satellite configuration and correction status. When setting filters it is important to note that data can be lost. If a survey location does not meet the defined criteria it will be excluded from the export and therefore no record will be included in the dBase table. As a result, land cover and land use survey information will be lost. In this export example, all features will be exported irrespective of correction or satellite parameters.

- Ensure that the option "Filter by GPS Position Info" is selected.
- Ensure that the satellite parameters are set to minimum values to allow the export of all features:
    - Minimum Satellites: 2D (3 or more SVs)
    - Maximum PDOP: Any
    - Maximum HDOP: Any
- As no real-time or post-processing correction has been applied to the data all positions including uncorrected must be exported. Check the "Uncorrected" option in the "Include positions that are" section.

The 'Position Filter' tab should appear the same as Figure B6.4.

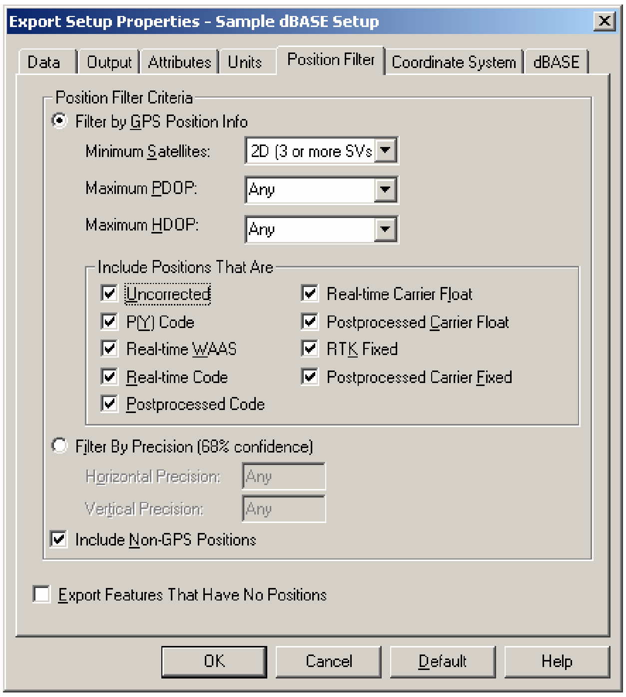


Figure B6.4 The position filter tab of the export setup dialog.

Coordinate System Tab
The 'Coordinate System' tab provides two alternative export options, data can be exported based on the current display coordinate system or using an export coordinate system. While no spatial element is being exported this coordinate system information should still be set as the parameters will control the system of the stated X and Y fields in the output table.

If the current display coordinate system, set within the main Pathfinder Office window is appropriate then the following instructions can be disregarded. Alternatively an export system must be set.

- If the current display coordinate system is not appropriate, select the "Use export coordinate system" radio button.
- Click on the button labelled 'Change' to open the "Coordinate Selector" dialog.

Using the drop-down menus within the "Coordinate Selector" dialog, an appropriate coordinate system can be set, for example in the case of latitude and longitude:

- Specify "Latitude/Longitude" as the system, using the drop-down menu.
- Specify "WGS 1984" as the datum.
- Click 'OK' to accept the coordinate system and return to the parameter setup window.

dBase Tab
- Ensure that the decimal symbol is set to 'Dot(.)'.

- Click 'OK' to accept the setup parameters and return to the "Export Utility" dialog.

- The changes made to the export parameters should be reflected in the summary at the base of the "Export Utility" dialog.
- Click 'OK' to accept the parameters set and proceed with the export

The export utility will proceed with the export process and the creation of a series of dBase files. A series of files are created as a unique dBase file is created for each feature type, i.e. the land use feature and third stage LCCS dichotomies. These files are named according to the feature label specified in the data dictionary.

- When export is complete an export completed dialog will be displayed. This includes a summary of the number of features exported. Ensure that the appropriate number of features, i.e. the number of survey points in the file, have been read and exported.

If there is a discrepancy between the number of features read and number exported, the export parameters, in particular the positional filter properties, should be checked.

- Click 'Close' to dismiss the "Export Completed" dialog.

It is important to note that the file naming conventions used in the export are standardised and set by the software. As a result, on running a second export process the output filenames will already exist, hence an overwrite files warning will be generated. To prevent file overwrite the original export files should be removed from the export folder and renamed.

- Using My Computer, navigate to the export sub-folder of the project folder. A series of dBase files should now be present.

Shapefile Format
A further alternative is to export the Trimble data file to an ESRI shapefile for display within a GIS.

- In the "Input Files" section of the "Export" dialog ensure that the imported data file is listed in the selected file list. If the file is not listed click on the 'Browse' button in the "Open" dialog, navigate to and open the appropriate Trimble data file.
- Ensure that the output folder is an appropriate location. By default this will be the export folder contained within the project folder.
- Using the drop-down menu set the "Export Setup" to "Sample ESRI Shapefile Setup".
- Click the button labelled 'Properties' at the base of the dialog to open the "Setup Properties" dialog.

The "Setup Properties" dialog contains all the parameters for the current export setup. Changing these parameters will influence the characteristics of the output shapefile. For the current export only a small number of parameters need be changed from their default values.

Data Tab

- Click the 'Data' tab at the top of the dialog.
- In the 'Data' tab ensure that the "Type of data to export" is set to "Features-Positions and Attributes" using the radio button and that the drop-down menu is set to "Export All Features".

Output Tab

- Click the 'Output' tab at the top of the dialog.
- Ensure the output files is set to "Combine all input files and output to the project export folder".

Attributes Tab

- Click the 'Attributes' tab at the top of the dialog.

The 'Attributes' tab contains options regarding the generated and feature attributes. Setting these parameters will influence the fields and data contained in the exported dBase table.

- At the top of the dialog, in the "Export Menu Attributes As" section, click in the radio button adjacent to "Code Value 1" to ensure it is selected.

This is very important as the data dictionary has been constructed to allow the export of coded values. As a result each of the attribute fields in the dBase file will contain an alphanumeric code based on the recorded data instead of a text description. For example the alphanumeric code of A1 in the life form main crop field of a cultivated or managed feature is indicative of broadleaved trees.

The base of the dialog contains a series of generated attributes which can be derived, by the software, from the GPS data. These generated attributes are grouped according to feature specific categories.

- From the "All Feature Types" group of the generated attributes section, select 'PDOP', by checking the appropriate check box. As a result an additional field will be added to the dBase table which contains the average PDOP value for each feature.
- From the "Point Features" group of the generated attributes section, select 'Horizontal precision'. The generated field values give an estimate of the horizontal precision of the averaged position for each feature. This field is a distance measure, the units of which will be set in the 'Units' tab.

The line feature and area feature groups can be disregarded as neither of these feature types are relevant to the survey.

The 'Attributes' tab should appear similar to Figure B6.2.

Units Tab

- Click the 'Units' tab at the top of the dialog.
- Select the "Use Export Units" option.

- Ensure that the "Export Units" are set to meters, square meters and meters per second. If this not the case click the button labelled 'Change'. In the select units dialog, which will open automatically, using the drop-down menus, select the specified measurement units. Click 'OK' to dismiss the dialog.
  The 'Export Units' tab should appear similar to Figure B6.3.

Please note the distance units used in this export are a recommendation and can be changed to meet the surveyors' requirements.

Position Filter Tab
- Click the 'Position Filter' tab at the top of the dialog.

The 'Position Filter' tab contains a series of parameters to control the criteria based filtering of positions during export. Filtering can be based on a series of parameters including satellite configuration and correction status. When setting filters it is important to note that data can be lost. If a survey location does not meet the defined criteria it will be excluded from the export and therefore no record will be included in the shapefile. As a result, land cover and land use survey information will be lost. In this export example, all features will be exported irrespective of correction or satellite parameters.

- Ensure that the option "Filter by GPS Position Info" is selected.
- Ensure that the satellite parameters are set to minimum values to allow the export of all features:
  - Minimum Satellites: 2D (3 or more SVs)
  - Maximum PDOP: Any
  - Maximum HDOP: Any
- As no real-time or post-processing correction has been applied to the data all positions including uncorrected must be exported. Check the "Uncorrected" option in the "Include positions that are" section.

The 'Position Filter' tab should appear the same as Figure B6.4.

Coordinate System Tab
The 'Coordinate System' tab provides two alternative export options, data can be exported based on the current display coordinate system or using an export coordinate system.

If the current display coordinate system, set within the main Pathfinder Office window is appropriate then the following instructions can be disregarded. Alternatively an export system must be set.

- If the current display coordinate system is not appropriate, select the "Use export coordinate system" radio button.
- Click on the button labelled 'Change' to open the "Coordinate Selector" dialog.

Using the drop-down menus within the "Coordinate Selector" dialog an appropriate coordinate system can be set, for example in the case of latitude and longitude:

- Specify "Latitude/Longitude" as the system, using the drop-down menu.

- Specify “WGS 1984” as the datum.
- Click ‘OK’ to accept the coordinate system and return to the parameter setup window.

ESRI Shapefile Tab

- Ensure that the “Export Tracking Themes” option is left unchecked.

- Click ‘OK’ to accept the setup parameters and return to the export utility.
- The changes made to the export parameters should be reflected in the summary at the base of the “Export Utility” dialog.
- Click ‘OK’ to accept the parameters set and proceed with the export

The export utility will proceed with the export process and the creation of a series of shapefiles. A series of files are created as a unique shapefile is created for each feature type i.e. the land use feature and third stage LCCS dichotomies. These files are named according to the feature label specified in the data dictionary.

- When export is complete an “Export Completed” dialog will be displayed. This includes a summary of the number of features exported. Ensure that the appropriate number of features, i.e. the number of survey points in the file, have been read and exported.

If there is a discrepancy between the number of features read and number exported the export parameters, in particular the positional filter properties should be checked.

- Click ‘Close’ to dismiss the “Export Completed” dialog.

It is important to note that the file naming conventions used in the export are standardised and set by the software. As a result, on running a second export process the output filenames will already exist hence an overwrite files warning will be generated. To prevent file overwrite, the original export files should be removed from the export folder or renamed.

- Using ArcCatalog or My Computer, navigate to the export sub-folder of the project folder. A series of shapefiles should now be present.

Appendix C

Appendix C

Bespoke GPS application

1. Design

1.1. Introduction

The requirements for any field data collection application are defined by the structure and methodology of LUCAS. Based on the FAO project needs and the LUCAS methodology requirements the following list has been created. This list provides a basis for assessing the abilities of existing software applications as well as providing a basis for development of a task specific application if required.

- Data
  - Is field survey input and recording supported?
  - Hierarchical data structure
  - Enforce data integrity
  - Dual themed – Land Use and Land Cover
  - Point recording
  - Universal data format
  - Data backup
- GPS Integration
  - DGPS compatibility
  - Recording of precision measurements
- Usability
  - User friendly
  - User driven
- Cost
  - Low cost

A detailed design of the final application is required to maintain the focus of the application so that the end product meets the exact requirements of the end user. Detailed design is also an aid to the code development of the application; the design provides a map on which to base the code. The design in this instance is based on the requirements laid down by LUCAS and the requirements set out in the terms of reference by the FAO.

The design breaks down into three levels. The first level is the identification and definition of the use cases, the second is the creation of use case diagrams which show how individual use cases and actors link together. The third level is the creation of data flow diagrams indicating in much more detail how data flows through the system and on which the application development can be based.

Consideration must also be made towards the design and layout of the output database. The database design shows the field layout for each table as well as how each table is related.

1.1. Use Cases

1.1.1. Core Application

Use cases detail the core procedures of the field data application. They are generated from the requirements of the project and consist of the actors and use cases that make up the application. The GPS interface use case is a standalone item that is essential to the functionality of the application.

- Create new Project

Main flow of events: The surveyor selects the Create New Project button that displays the New Project form. The surveyor enters the project name and selects which classification systems are to be used and clicks create project. The project name is validated, the project database is created and a confirmation of the new project being created is displayed and returns the surveyor to the main page.

Exceptional flow of events: If the surveyor enters a project name that already exists, a prompt is raised requesting them to enter a new project name.

Exceptional flow of events: If the surveyor clicks select land cover classification the system displays the select classification screen.

Exceptional flow of events: if the surveyor clicks select land use classification the system displays the select classification screen.

Exceptional flow of events: If the surveyor clicks the cancel button the create new project window is cancelled and the surveyor returned to the main menu page

- Open Existing Project

Main flow of events: The surveyor selects the Open Existing Project button that displays the open project form. The surveyor selects the project to open and clicks the open project button. The surveyor is taken to the first data entry page.

Exceptional flow of events: If the surveyor clicks the cancel button the open project page is cancelled and the surveyor is returned to the main page.

Exceptional flow of events: If no projects are found a prompt is raised indicating that a project needs to be created first and opens the create new project page.

- Data Entry

Main flow of events: The surveyor is able to add data to the selected project, including area and sample ID's, general sample point details, land cover details, land use details and photograph details. When the surveyor starts recording each point the GPS position is recorded and added to the database.

Exceptional flow of events: If the sample point reference already exists the user will be prompted to check and re-enter the reference.

Exceptional flow of events: If the area sample reference already exists the user will be prompted to check and re-enter the reference.

- Close Project

Main flow of events: Surveyor selects close project. All records are saved to the database and the surveyor is returned to the main page.

Exceptional flow of events: If the surveyor selects add another sample point they are returned to the beginning of the data entry process.

1.1.2. GPS Interface

Main flow of events: The GPS signal is received by the GPS receiver and then translated to produce latitude and longitude values and a PDOP figure for the precision of the GPS position. Live coordinates are displayed along with the PDOP value. GPS coordinates are collected over the period of the point data collection and averaged to increase the positional accuracy.

Exceptional flow of events: If there is no data at the selected port the system raises a prompt and returns the surveyor to the port selection interface.

Exceptional flow of events: If the PDOP value rises above a user defined level a prompt is raised and the collection of GPS data is suspended until the value is lower than the threshold again.

Exceptional flow of events: If GPS data is lost the surveyor is prompted and returned to the start of the sample point data collection process. The surveyor is prompted to wait for coverage to return.

1.2. Use Case Diagrams

Combining the uses cases and defining the links between them allows the designer to demonstrate the full functionality of the application. This functionality can be described through the production of use case diagrams.

Use case diagrams describe graphically the interactions between the systems, the system components and the users. Interaction between the core components is through the actor (surveyor) (Figure 1.1).

Further detail is introduced as the core account use case is broken down into its component parts. In these instances there are interactions shown between both the user and other system components.

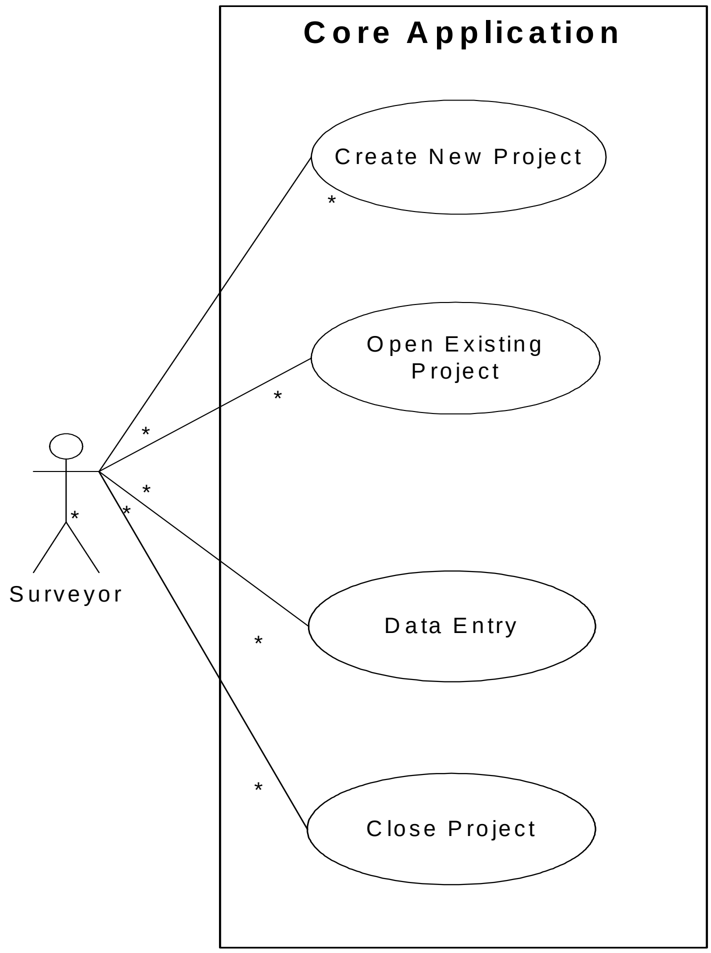


Figure 1.1 Core Application Use Case diagram

One of the main components of the application is the GPS interface. This allows the application to connect to a GPS receiver and record GPS coordinates. A use case (Figure 1.2) has been generated providing an outline of how the interface should operate.

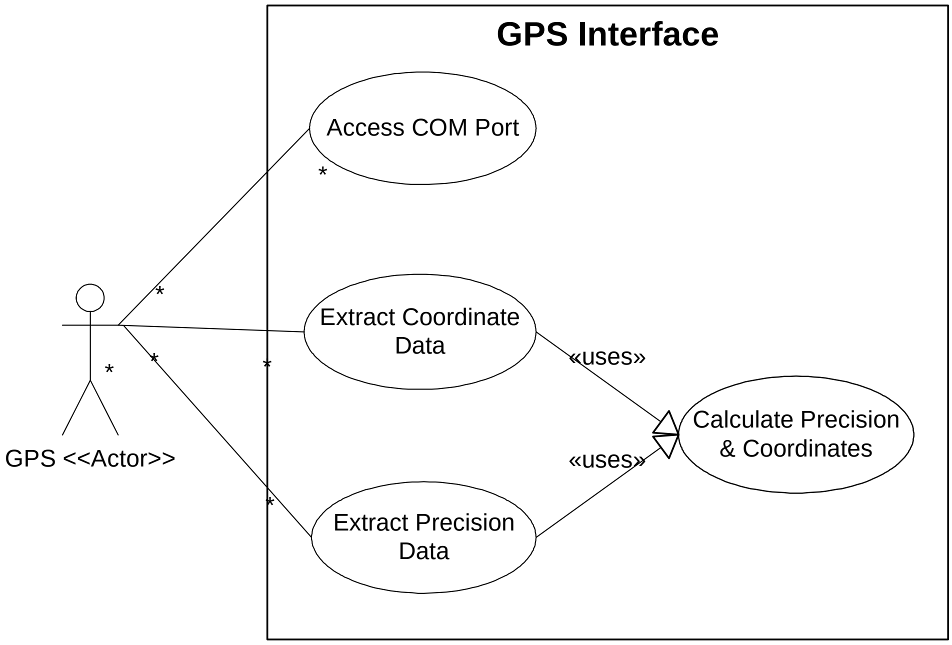


Figure 1.2 GPS Interface Use Case diagram

The use cases provide the raw structure of the application, identifying what is required of the application and how each section is linked. For further development a more detailed design and structure is needed.

1.3. Data Flow Diagrams

The use cases detailed above provide an outline for the functionality of the application. For more detailed planning a set of data flow models are produced. Data Flow Diagrams (DFD) depict the flow of data through a system plus any processing that the system performs (Whitten et al, 2001). The data flow diagram allows a developer to visualise what is required for the development of the application (Figure 1.3).

The application designer starts with an overall DFD and progresses through each process creating new, more detailed DFD's until no further breakdown is possible, this is known as process decomposition. Decomposition is the breaking down of a system into its component subsystems, processes and sub processes (Whitten et al, 2001). For this project we will focus on one specific process, that of the GPS interface.

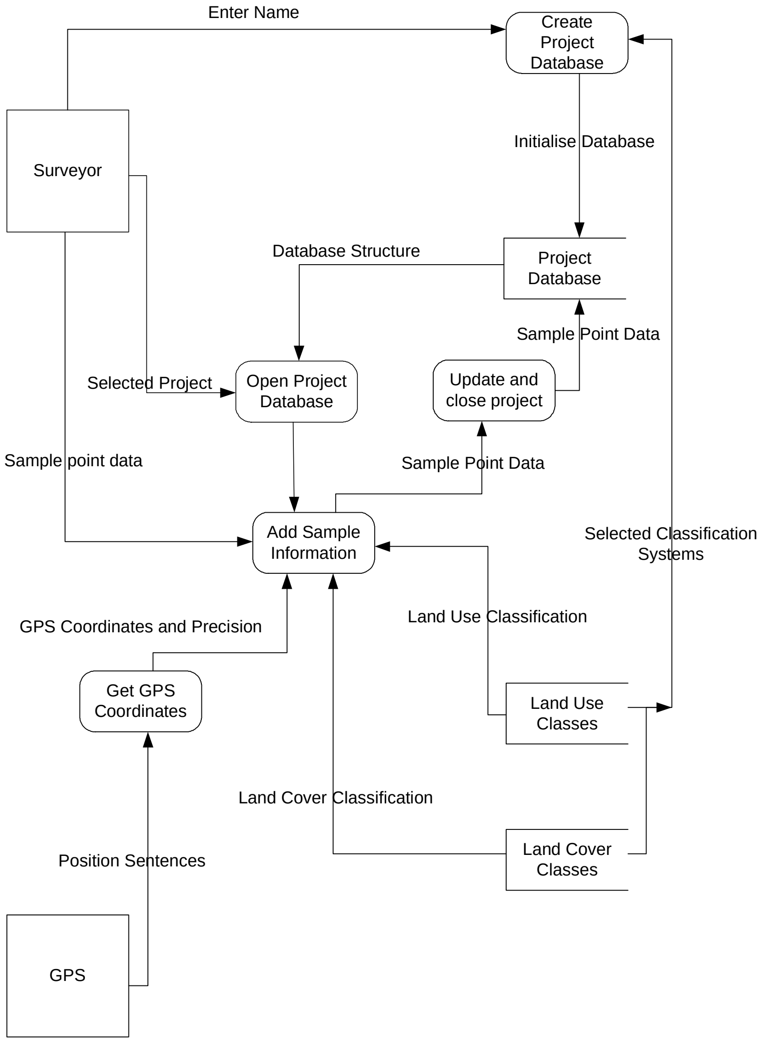


Figure 1.3 Summary Data Flow Diagram

The purpose of the GPS interface is to provide the link between the GPS receiver and the application, and to extract the required information from the GPS data. The interface consists of a number of processes (Figure 1.4) that provide the required functionality. Within the GPS interface process shown in Figure 1.3 there are a subset of processes which are the building blocks of the process. A further level, beyond that in Figure 1.4 is not necessary as it would consist of actual code.

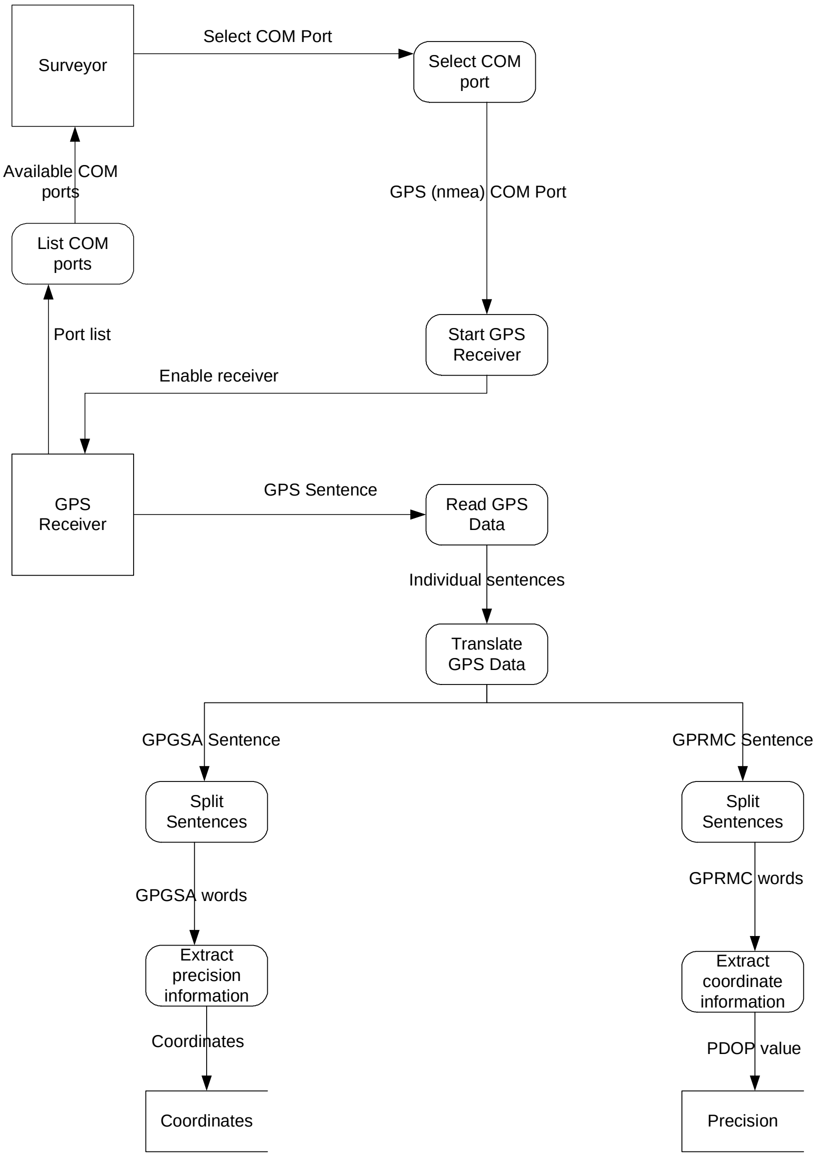


Figure 1.4 Detailed DFD for GPS interface

The external agents in the GPS interface DFD (Figure 1.4) are the surveyor who provides input into the setup of the interface i.e. selects which COM port the GPS receiver sends the GPS sentence to. The other external agent is the GPS receiver. The GPS receiver converts the incoming satellite information and converts it to a set of GPS sentences which provide the positional information on which the remainder of the processes are based.

The outputs from the process are three variables: latitude, longitude and PDOP which are made available for the rest of the application.

1.4. Database Design

There are three databases linked to this application. The primary one is the output database where all the field survey point data is saved. The second and third databases store the classification reference data.

The primary key for the project output database is a combination of the PSU and SSU identities, all other point information is linked through this primary key. Within the database there are six data tables, five of these hold the point data and the sixth holds reference information on which classification databases were used. The data tables (Figure 1 .5) are all related through the sample identity field.

The contents of the observation, land cover, land use and photograph tables are prescribed by the information requirements laid down by LUCAS. The data could have been stored in a single table, however by splitting it into different tables it allows easier break down and analysis of the data.

The classification reference databases provide the nomenclature information for the land use and cover types. These databases have a hierarchical structure that leads the user from a broad classification through to a much more detailed classification. Class selection within the application is achieved by stepping down through the hierarchy until the fine detail level is reached.

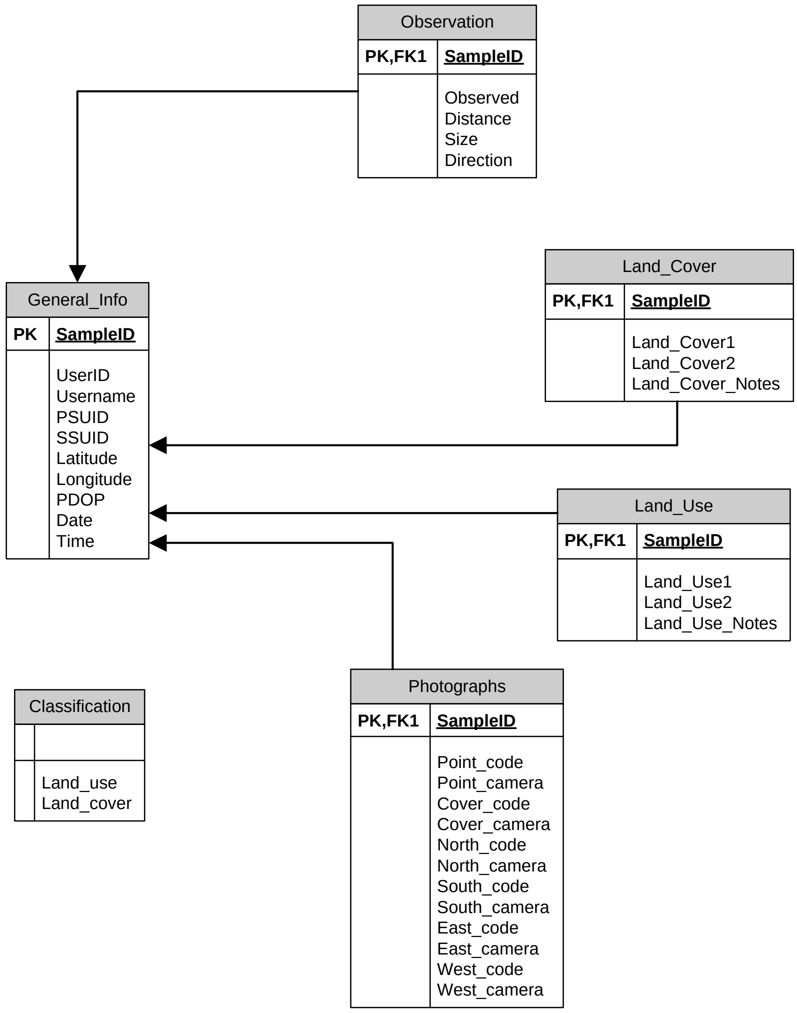


Figure 1 .5 Project database design.

1.5. Conclusion

With a detailed design for the application complete it is now possible to start developing the application code. The design provides the scaffolding on which to build the application. By carrying out a detailed design before starting the development process it ensures that the original goals of the project are adhered to. The developer will use the design as a step by step guide on how the application should look, what its inputs and outputs are and how all the processes link together.

The design outlines an application that meets the terms of requirements of LUCAS and the project. It creates an easy to use application that supports the hierarchical structure of LUCAS and records the GPS coordinates of the sample points. The GPS functionality and accuracy is not as great as that found in ArcPad or TerraSync but the application is standalone and cost effective.

2. **Development**

2.1. Introduction

The overall design of the application, detailed in section three, is to create and add data to a project database. The development process transforms these designs into a working application. The development process involves creating the user interfaces and coding the functions of the application. Development is carried out in a debug environment allowing the application to be tested as it is built.

2.2. Programming Language

There are a number of programming languages that can be used and selection of the correct language is essential. The primary requirement of the language is that it can be used to create programs for installation on a mobile CE device. Farmer (2006) has shown that Microsoft Visual Basic.NET (VB.NET) is suitable for this task and will be used for the development of the field data application.

VB.NET is an object orientated programming language that comes as part of the Visual Studio .NET group of products. It is designed for programming in the Windows and Web environments (Cowell, 2002).

VB.NET is part of Microsoft Visual Studio 2003 which has been used, with the addition of some add-ons, to develop the application. A newer version of Visual Studio exists but is not available for this project.

2.3. Additional Requirements

Databases are not supported in this version of VB.NET. To enable database creation and communication ADOCE 3.1 from In the Hand is required. This allows creation of Compact Databases (cdb) which when transferred to a desktop PC are converted, by Microsoft ActiveSync, into Microsoft Access databases.

The GPS interface links to the GPS receiver through a specified COM port. Visual Studio 2003 does not support communication with the COM ports. To overcome this SerialTools is installed which provides this support. SerialTools is available from Franson (www.franson.com) at a cost of $29.95.

To enable the testing of the application before installation on the mobile device a standard emulator, supplied with Visual Studio, is used which mimics the operation of the mobile device. This saves time and allows the programmer to debug the program before final release to the mobile device. To check the GPS interface a further emulator is required. GpsGate allows you to simulate a GPS and send the signal to a specified COM port. GpsGate is available from Franson at a cost of $29.95. For this project a free trial version of GpsGate was sufficient.

2.4. Application Development

Development of the application was split into three identifiable stages. Firstly the graphical user interface (GUI) was created. This is the interface that the surveyor uses for accessing the functionality of the application. Secondly, a test GPS interface was developed which enables the full testing of this primary component before it was installed in the main application. Finally, the main application coding was generated.

2.4.1. The GUI

The GUI consists of a sequence of forms allowing the surveyor to select and add data to the project database. The primary form (Figure 2.1) is the main options screen. From here the user is able to create new projects, setup the GPS interface and add data to the project.

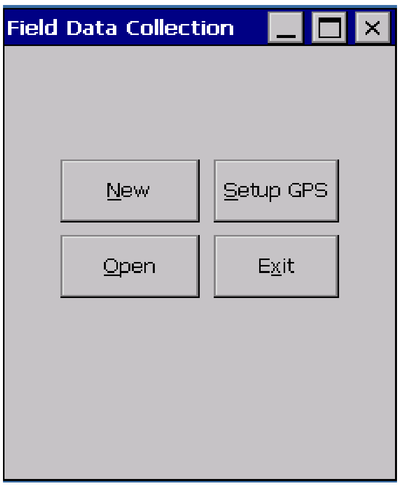


Figure 2.1 Main options form

Data entry is achieved through a sequence of data entry forms that lead the user through the process ensuring that all of the required information is recorded. The data entry sequence is split into the specific areas identified within LUCAS i.e. an observation, land cover, land use and photographic entry forms.

The data entry forms for land cover and land use allow the surveyor to select the land cover/use type based on the hierarchical structure of the classification system (Figure 2.2).

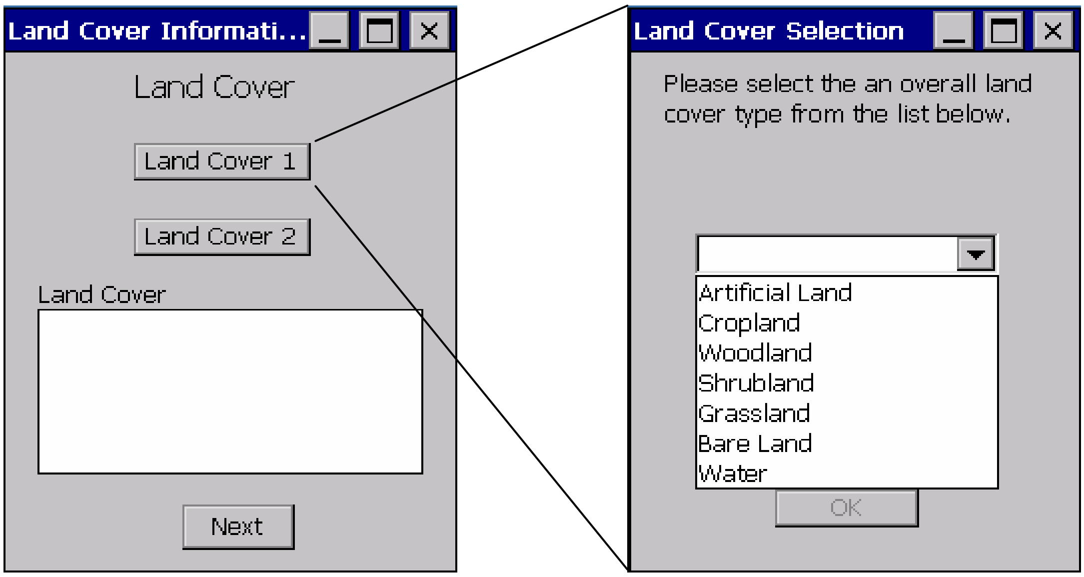


Figure 2.2 Land Cover Selection forms

The final form (Figure 2.3) closes the data entry for the sample point. The user has the option of moving to the next sample point within the PSU or exiting to a new PSU or the options screen. Behind this form code completes the data entry process and saves the sample data to the project database

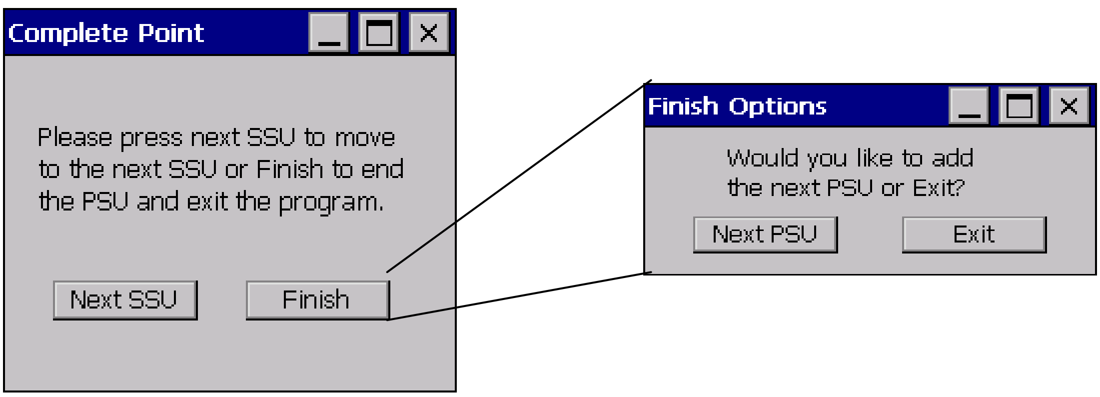


Figure 2.3 Finish screen and options

2.4.2. The GPS Interface

The GPS interface was initially developed as a standalone test program which could be installed separately on the mobile device for quick testing. The interface was developed in such away that it could be easily transferred to the main application.

A GPS receiver produces positional information in a number of formats. The most common of these is the National Marine Electronics Association (NMEA) format. NMEA consists of a number of individual data sentences containing information that is based on the first word of the sentence (Person, 2004). An example of a sentence is:

$GPRMC,132542.584,A,5200.18,N,00025.40,W,3.2,275.35,010806,,*1A

For this application two sentences will be used: GPRMC, and GPGSA. The NMEA data is sent by the GPS receiver to a specific COM port. With the GeoXT this is COM 2.

The interface consists of a number of processes, as detailed in the design stage. The first phase accesses the COM port of the GeoXT to which the GPS data is sent by the receiver. This was accomplished through the use of the SerialTools tool. Having accessed and enabled the COM port, GPS data is sent to it. The next stage of the interface is to read the data from the port and translate it (Figure 2.4).

Information is sent to the COM port as data sentences containing all the GPS information. The interface identifies the two required sentences (GPRMC and GPGSA) and breaks them down into their individual words so that the relevant information can be extracted.

The GPRMC sentence contains coordinate information in latitude and longitude plus information on whether there is sufficient data to generate a fix. The GPGSA sentence is the precision sentence and contains PDOP, HDOP and VDOP information. Once the information has been extracted it is stored within a group of variables that can be accessed by the rest of the application. The GPS data is sent to the

COM port every second and is recorded by the interface every second.

```
Public Sub timGPS_Tick(ByVal sender As Object, ByVal e As System.EventArgs) Handles
gpsTimer.Tick

Try
'Com port is accessed and read every second

gpsdata = gpsPort.Read("$GPRMC", "*", 0)
Dim counter As Integer

Do While counter < 500 And gpsdata Is Nothing
        gpsdata = gpsPort.Read("$GPRMC", "*", 0)
        counter += 1
Loop

'Check whether there is data on the COM port
If gpsdata Is Nothing Then
        'if there is no data then the program returns you to the beginning
        MsgBox("No data on port")    'Raise an error if there is no data
        gpsPort.Enabled = False
        gpsTimer.Enabled = False
Else
        'if there is data on the COM port then the data is translated and recorded
        gpsprecision = gpsPort.Read("$GPGSA", "*", 0)
        ReadGPGSA()
        ReadGPRMC()
End If

Catch ex As Exception
MsgBox(ex.Message)
End Try

End Sub
```

Figure 2.4 Sample of code from the GPS interface.

Within the application GPS data is recorded over the time it takes to enter the point data and then averaged to produce a more accurate position. Throughout the data collection period the PDOP is monitored and if it falls below a specified level GPS data collection is suspended and the user notified.

Error handling and error checking is present throughout the interface coding so that the risk of the application falling over is reduced. Checks are made as to whether there is data on the port and whether it is the correct data. Monitoring the precision so that it doesn't get too high is a further error handler.

2.4.3. The Database application

The core of the application is that of a database management system. The application creates and updates a project database with land survey information. The ADOCE tool is used to provide database support. This tool needs to be installed on the mobile device to enable it to operate. The surveyor is provided with two main options when starting the application.

The create project database option generates an empty database with a name selected by the surveyor. The database is created with six empty fields (Figure 1 .5). The surveyor also identifies at this stage the two classification systems that will be used. The open project option allows the surveyor to open a project and add data. Data entry is achieved through a sequence of data entry forms that lead the surveyor through each requirement of the LUCAS methodology. Data is added to the relevant tables within the database whenever the user moves to the next form (Figure 2.5). At the end of the data entry process the GPS data is added to the database and the user is asked to add a further point, move to the next PSU or exit the project. At the same time the GPS information is added to the general information table.

```
Private Sub btnNext_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles
btnNext.Click

    'Check to see if a Land cover value has been entered
    If finalLC1 Is Nothing Then
        MsgBox("Please enter a primary land cover class")
        Exit Sub
    End If

    If finalLC2 Is Nothing Then
        finalLC2 = ""
    End If

    'Save selected land cover information to database and move to next form
    Call opendatabase()
    rs = New InTheHand.AdoceNet.Recordset

    rs.Open("Land_Cover", conn, InTheHand.AdoceNet.LockType.Optimistic)

    'Add data to fields
    rs.AddNew()
    rs.Fields("SAMPLEID").Value = psu & ssu
    rs.Fields("LAND_COVER1").Value = finalLC1
    rs.Fields("LAND_COVER2").Value = finalLC2
    rs.Fields("LAND_COVER_NOTES").Value = txtLCNotes.Text

    'Update and close record
    Call updateandclose()

    Timer1.Dispose()

    shut = True

    'Open next form
    Dim openform As frmLandUse
    openform = New frmLandUse
    openform.Show()
    openform = Nothing

    Me.Close()

End Sub
```

Figure 2.5 Sample of code for adding the Land Cover reference to the database

Through out the data entry phase error checking and handling is taking place ensuring that data integrity is maintained and that all of the required information is recorded. An example of this is that the surveyor must enter a land use value; the program will not allow them to move to the next stage until this is accomplished.

2.5. Installation/Deployment

For deployment on a mobile device the application is compiled as a Cabinet (CAB) file. This file is then transferred to the mobile device using Microsoft ActivSync. The CAB file contains all the information it requires to run including the SerialTools Dynamic Link Library (dll) file and the ADOCE dll. Once copied to the mobile device the CAB file is run which installs the application.

VB.NET creates a number of different CAB files which can be used. The CAB files are processor specific so care must be taken when transferring the correct CAB file to the mobile device.

The application also requires the classification databases to operate. These can be created on a desktop PC and transferred to the mobile device in the same way as the application. For this application a LUCAS survey database has been created (see accompanying CD-ROM) which contains both the land cover and land use reference information.

3. Field Testing

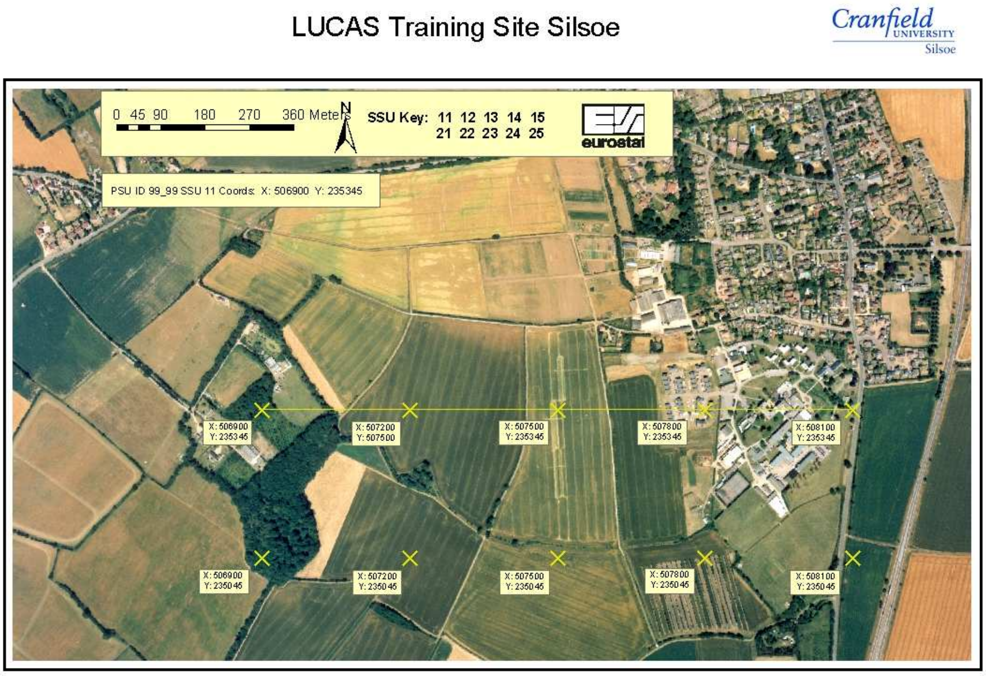
3.1. Introduction

The aim of this test is not to carry out the LUCAS survey but to demonstrate that the new application functions as it should and meets the requirements laid out in section 1.1. This field test will result in a dataset that contains all the recorded data that is required from the chosen survey methodology.

3.2. Methodology

The LUCAS methodology detailed in section 4.4 of the main report will be used as a basis for this field test. The test will be carried out on a PSU site adjacent to the university site in Silsoe. Each SSU (Figure 3.1) will be visited and observation, land cover, land use and photographic details will be recorded.

The methodology aims to test the functionality of the GUI, the database interface and the GPS interface. The resultant database will be displayed providing evidence that the application records and saves the required information.



Source: Farmer, 2006

Figure 3.1 Field test sample points

Under a separate investigation a comparison will be made between positions recorded using the Field Data Collection application and TerraSync. Positions will be recorded using the raw GPS data which will not be corrected in any way. Five survey points will be chosen and GPS coordinates are recorded twice per application at each point. A difference in distance between the application position and the TerraSync position will be calculated as a comparison.

3.3. Results

The project database created during the field test contains six tables that can be related through the sample ID number (Figure 1 .5). These tables contain the data collected during the field survey; some of this data is generated automatically, but most is generated through the user interface.

The general information table (Table 3.1) contains the broad information on the survey, i.e. sample number, surveyor identity and sample coordinates. The sample point observation, land cover (

Table 3.2), land use and photograph reference information is contained in separate tables.

Table 3.1 General Information database table

SAMPLEID	USERID	USERNAME	PSUID	SSUID	LONGITUDE	LATITUDE	PDOP	DATE	TIME
00111	gg06	Graeme Gould	001	11	0.440379624652778W	52.0056874142361N	3	07/08/2006	03:56:08 PM
00112	gg06	Graeme Gould	001	12	0.43999245W	52.0057676172515N	3	07/08/2006	03:57:58 PM
00113	gg06	Graeme Gould	001	13	0.434612746341463W	52.0058640752033N	2	07/08/2006	04:06:05 PM
00114	gg06	Graeme Gould	001	14	0.429301242718447W	52.0056929647249N	3	07/08/2006	03:06:52 PM
00115	gg06	Graeme Gould	001	15	0.424733943333333W	52.0054578925N	3	07/08/2006	03:12:36 PM
00121	gg06	Graeme Gould	001	21	0.441777756770833W	52.002758165625N	4	07/08/2006	03:49:32 PM
00122	gg06	Graeme Gould	001	22	0.437402630654762W	52.0040503011905N	3	07/08/2006	03:41:52 PM
00123	gg06	Graeme Gould	001	23	0.434893765060241W	52.0030557849398N	3	07/08/2006	03:37:53 PM
00124	gg06	Graeme Gould	001	24	0.429379491102757W	52.0028738422306N	3	07/08/2006	03:28:37 PM
00125	gg06	Graeme Gould	001	25	0.424914728021978W	52.0028789254579N	2	07/08/2006	03:19:08 PM

Table 3.2 Land Cover database table

SAMPLEID	LAND_COVER1	LAND_COVER2	LAND_COVER_NOTES
00111	C21		
00112	B11		
00113	B53		
00114	A11		
00115	A22		
00121	C21		
00122	B11		
00123	B53		
00124	E01	C21	
00125	F00		

The codes stored in the land cover and use tables can be referenced back to the classification databases to provide the descriptions for the identified land classes. The codes stored in the photograph reference table allow the photograph to be linked to a sample point.

The comparison of positions recorded by the field data application and TerraSync shows very little difference (Table 3.3), in most instances it is less than 50cm.

Table 3.3 Positional differences between the new application and TerraSync

	TerraSync		Field Data Collection		
ID	Longitude	Latitude	Longitude	Latitude	Difference (m)
11	-0.427898799	52.005121909	-0.427900548	52.005121828	0.120
12	-0.427898264	52.005121165	-0.427900935	52.005121798	0.196

13	**-0.428020823**	**52.004016952**	**-0.428021494**	**52.004016880**	**0.047**
14	**-0.428019380**	**52.004016047**	**-0.428021055**	**52.004014707**	**0.188**
15	**-0.425734005**	**52.004294064**	**-0.425733280**	**52.004294054**	**0.050**
21	**-0.425733476**	**52.004293648**	**-0.425733159**	**52.004294412**	**0.088**
22	**-0.426231210**	**52.006248424**	**-0.426230588**	**52.006248265**	**0.046**
23	**-0.426232486**	**52.006249076**	**-0.426228889**	**52.006248027**	**0.273**
24	**-0.428579800**	**52.005823641**	**-0.428562329**	**52.005834203**	**1.679**
25	**-0.428581503**	**52.005821582**	**-0.428583153**	**52.005824538**	**0.348**

3.4. Discussion

The field test was a success. The application recorded all of the required information including the sample point coordinates from the GPS. This information can now be incorporated in to a GIS for further analysis.

The field test did raise a few questions that can be looked at in the future. One concern was whether the position should be recorded if the sample point is inaccessible. If you do record the coordinates for the location that you are at then you can't use them to position the sample, however if you don't record them then returning to the point at another time is difficult.

The GPS coordinates recorded from the NMEA signal compare very well to the coordinates recorded through TerraSync. There are some minor variances between the two. These can be attributed to the recordings being taken at slightly different times as it was impossible to record the positions simultaneously.

3.5. Conclusion

The application works well, it meets the requirements identified in section 1.1 and produces a clearly defined set of results that can be easily used by other software applications.

There are some improvements and amendments that can be made to future versions of the application and these are detailed in the next sections.

4. Future developments

4.1. Introduction

There are developments that can be made at all levels of the project. The classification system can be developed so that it can be used around the world, the methodology can be developed based on changes in the study area and the software can be developed to increase the accuracy of the positioning or incorporate different classification systems.

4.2. Classification Systems

As discussed in section two the LUCAS classification has its limitations in that it is designed for use within Europe. For use within Africa the land cover and use classification would need to be changed to take in to account the different environments.

The FAO has its own Land Cover Classification System (LCCS) that is universally applicable and can be used in any land cover project anywhere in the world. LCCS is universal and is not dependent on geographic location and can be adapted for use in any climatic zone and environment (Di Gregorio, 2005).

LCCS is a two phase a priori classification process that generates clear and systematic land cover classes by combining sets of hierarchically arranged classifiers (Di Gregorio, 2005). Of particular interest to land degradation studies LCCS can also include environmental attribute information such as climate, landform, altitude, soil lithology and erosion.

LCCS does not contain any provision for collecting land use information, however the FAO does have a land use database which could be utilised to generate a land use classification system.

4.3. Survey Methodology

There are opportunities for development of the survey methodology. As discussed in section 4 of the main text**Erreur ! Source du renvoi introuvable.** LUCAS within Europe has evolved and now instead of using an $18km^2$ grid a $2km^2$ grid is used. This change has resulted from the lessons learnt during the first LUCAS surveys.

The same can be true for carrying out LUCAS within Africa. The selected methodology for this project is a starting point from which lessons can be learned. Changing the size of the sampling grid, or increasing the sample points are a future development that may improve the effectiveness of the survey.

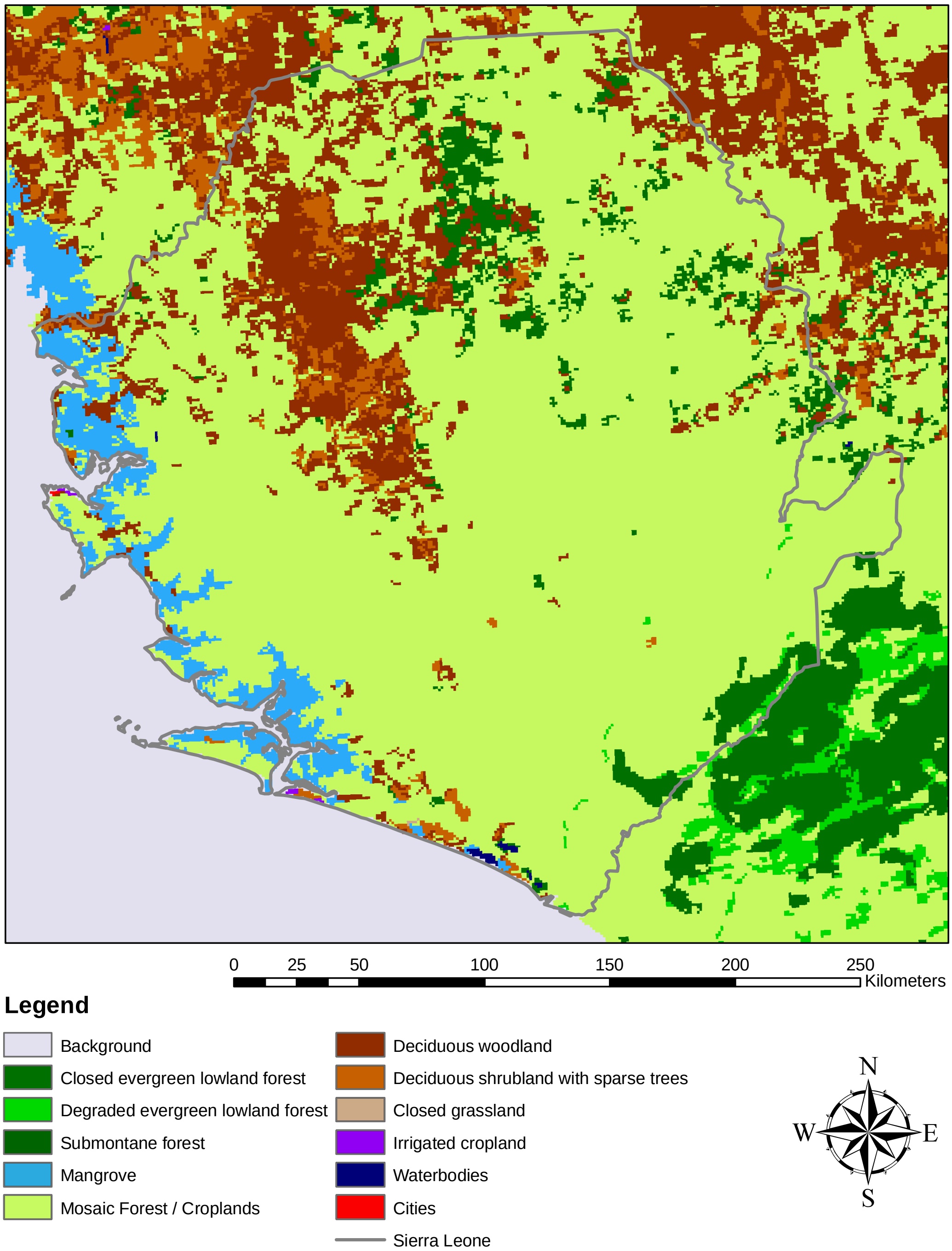
4.4. *Software*

As discussed in section 3.4 there are many improvements that can be made to the application. Some of the most significant future developments are as follows:

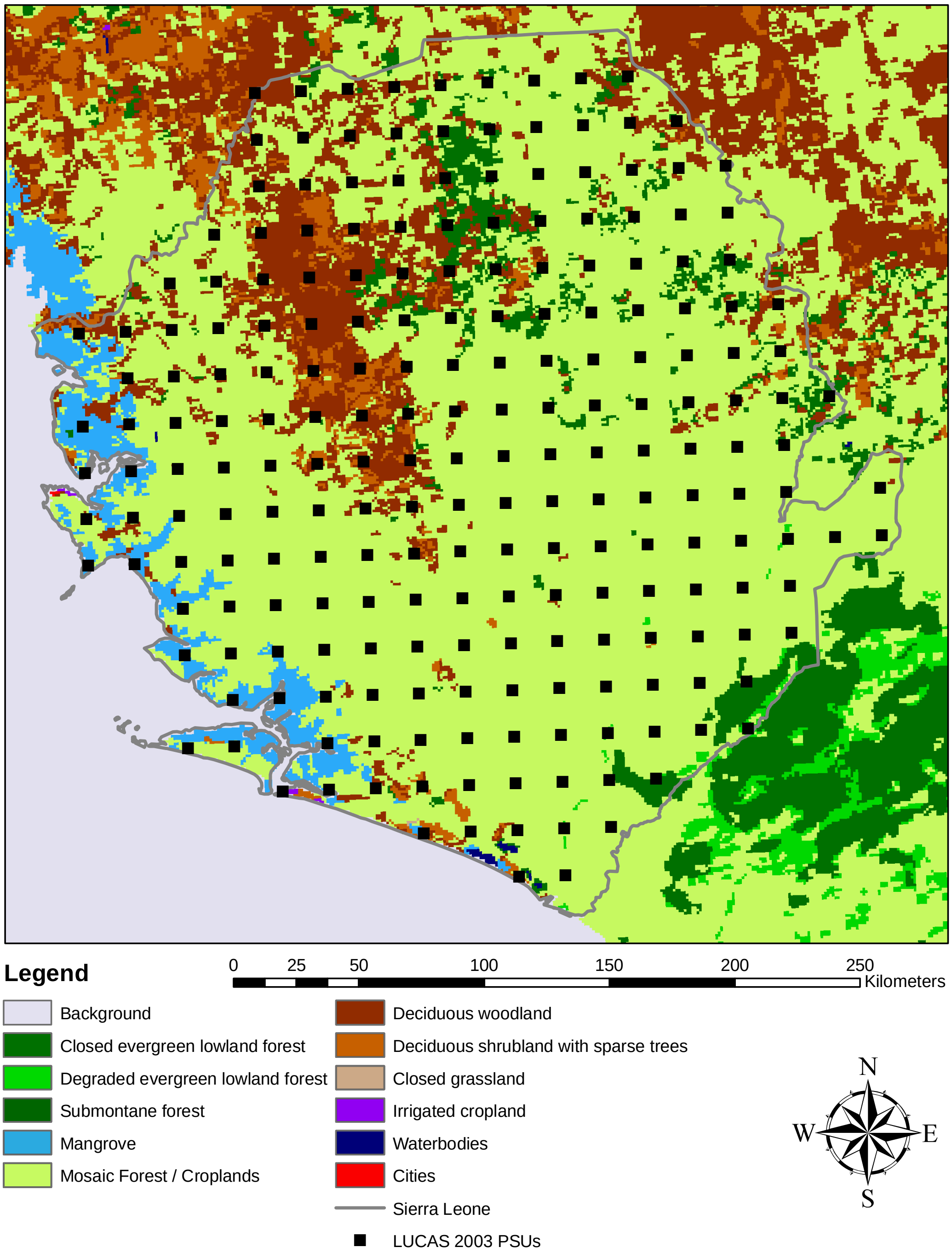
- Record the carrier phase signal to allow post processing of the positional information
- Inclusion of a file containing the coordinates for each SSU would provide a method of navigating to the point as well as providing a quality check for the record position. If the difference between the two was less than a specified threshold then the point could be classed as visited. If it was above then the point could be classified as observed from distance or within a forbidden zone.
- Placing the GPS interface component within a separate class enabling it to be included in other application easily
- Increase the application adaptability to include other classification systems
- Addition of a delete button enabling the user to delete a sample point.
- Increase the control the user has over the GPS interface, i.e. provide control over how often the GPS data is collected
- Allow the recording of positional data in a range of different datums.
- Incorporate more GPS information such as the number of satellites in view.

Appendix D

Appendix D1: GLC2000 for Sierra Leone



Appendix D2: Primary Sample Units for the implementation of the LUCAS 2003 methodology



The estimation (1) of the area for a given land use / land cover category based on the sample above is as follows (adapted from LUCAS, 2002):

(1) $$\hat{a} = \frac{A}{m} \cdot \sum_{i=1}^{m} \sum_{j=1}^{n} \frac{y_{ij}}{n_i}$$

where

$\hat{a}$ = estimated area of the land use/land cover in the considered geographic region
A = area of the considered geographic region
m = number of PSU in the considered geographic region
y_{ij} = 0, 0.5 or 1, the amount of land use/land cover in the SSU j within the PSU i
n_i = number of SSU within the PSU i

The internal and external variance of PSU may be calculated and the total variance (2) is the sum of those.

(2) $$v_{\hat{a}_h} = \frac{A^2}{m} \times \left[\left(\frac{M-m}{M} \right) \times \frac{1}{2d} \times \sum_d \left(y_{hi} - y_{hi-1} \right)^2 + \frac{1}{M} \sum_{i=1}^{m} v_2\left(y_{hi} \right) \right]$$

where

$$v_2\left(y_{hi} \right) = \frac{1}{n_i} \times \frac{1}{2d_i} \times \sum \left(u_{hi} - u_{hi-1} \right)^2$$

and where then

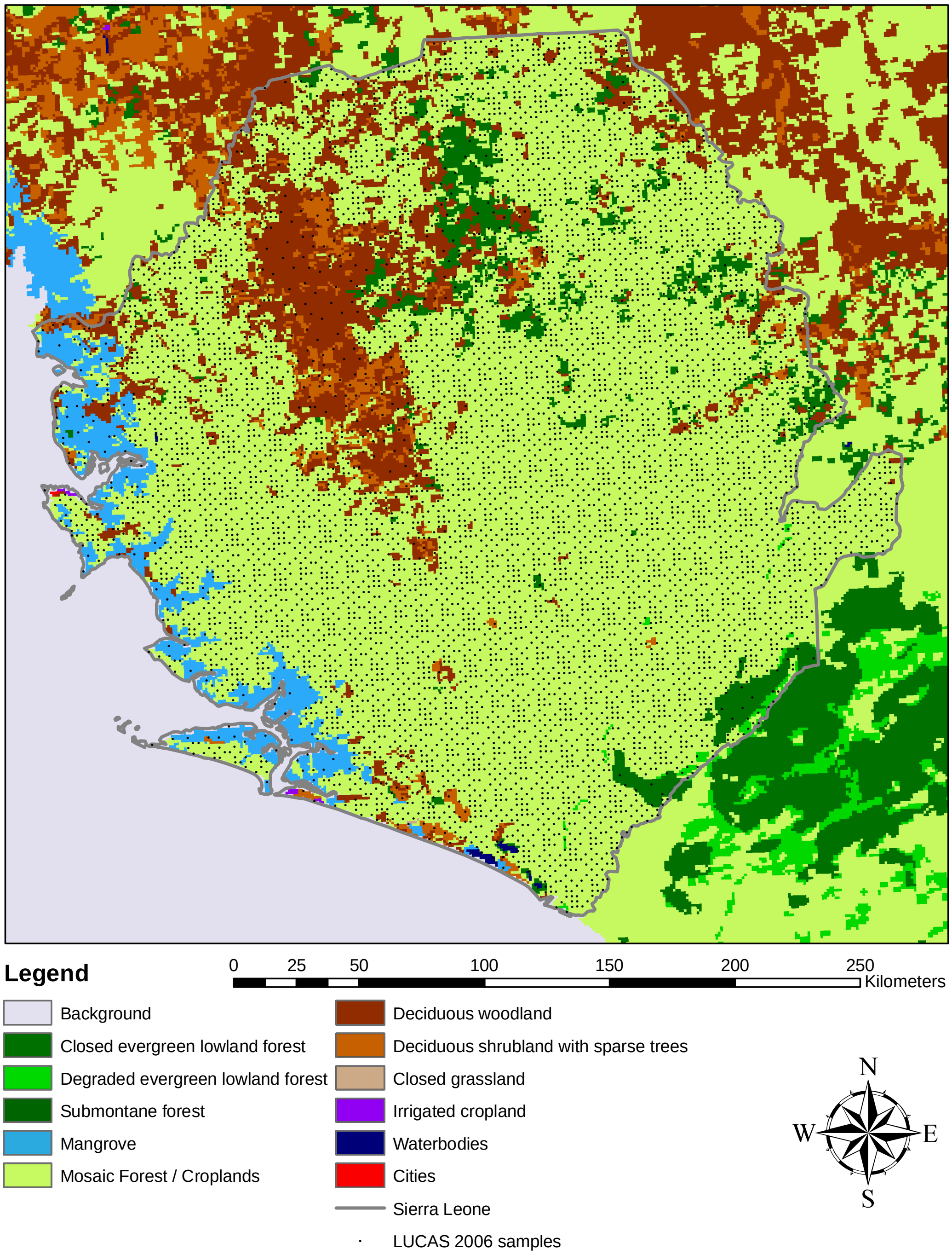
A = area of the considered geographic region
m = number of PSU in the considered geographic region
n = number of SSU in the considered geographic region
y_{ij} = 0, 0.5 or 1, the amount of land use/land cover category h in the SSU j within the PSU I
n_i = number of SSU within the PSU I
d_i= number of pairs of observation points taken
u_{hi} = indicative variable associated to the calculation of the variance of the considered category

In this formula of variance $u_{hi} - u_{hi-1}$ is zero, if both land covers on the SSU are same ones. If both land covers differ from neighbouring SSU then $u_{hi} - u_{hi-1}$ is one. Otherwise $u_{hi} - u_{hi-1}$ is 0.5.

Appendix D3: Sample size and effective sample rates for the LUCAS 2006 methodology in Sierra Leone

Class	Value	Sampling rate	Replicates	Master sample	Sample	Effective Sampling rate
Closed evergreen lowland forest	1	10%	8	878	84	10%
Degraded evergreen lowland forest	2	30%	24	59	18	31%
Submontane forest	3	10%	8	2	1	50%
Mangrove	6	10%	8	744	69	9%
Mosaic Forest / Croplands	7	50%	41	13718	6958	51%
Deciduous woodland	10	10%	8	2056	200	10%
Deciduous shrubland with sparse trees	11	20%	16	399	83	21%
Closed grassland	13	40%	32	1	1	100%
Irrigated cropland	20	50%	41	7	1	14%
Waterbodies	26	10%	8	17	2	12%
TOTAL				17881	7417	

Appendix D4: Final Sample for the implementation of the LUCAS 2006 methodology in Sierra Leone



The estimation of the area for a given land use / land cover category based on the sample above is as follows (adapted from LUCAS, 2006):

$$\bar{y}_{st} = \sum_{h=1}^{L} w_h \bar{y}_h = \sum_{h=1}^{L} w_h \frac{\sum_{i=1}^{n_h} y_{hi}}{n_h} \quad \text{where} \quad w_h = \frac{D_h}{D}$$

D is the surface of the area of interest

D_h is the surface of stratum *h*.

For the calculation of variance of land cover area :

$$v(\bar{y}_{dst}) = \sum_h w_h s_h^2 \left(\frac{1}{n' \nu_h} - \frac{1}{N} \right) + \frac{N-n}{(N-1)n'} \sum_h w_h (\bar{y}_h - \bar{y}_{dst})^2$$

where N is the size of the population in the whole region.

Since a point is considered to have a size 3x3 m

$N = \text{region area in hectares} / 0.0009$ (1/N is very small and can be discarded)

s_h^2 is an estimate of the variance of y (not of $\bar{y}$)

In this case we use an estimate of the local variance:

$$s_h^2 = (1 - f_h) \frac{\sum_{i \neq j} \delta_{ij} (y_i - y_j)^2}{2 \sum_{i \neq j} \delta_{ij}} \quad \text{Where} \quad f_h = {n_h}/{N_h}$$

δ_{ij} is a decreasing function of the distance between i and j : $\delta_{ij} = \frac{1}{d(i, j)}$

For countries where a stratification based on photo-interpretation of a pre-sample of points (regular grid) is applied, we have, for each *i*:

$$\delta_{ij} = \begin{cases} 1/d(i, j) & \text{if } j \text{ is among the 8 closest points to } i \text{ in the stratum} \\ 0 & otherwise \end{cases}$$

When there is no stratification, an alternative is:

$$\delta_{ij} = \begin{cases} 1/d(i, j) & \text{if } d(i, j) < 3000\ m \\ 0 & otherwise \end{cases}$$