Methodology for the Production and Updating of Agricultural Land Use/Cover Data Set

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Key words: agriculture, land use/cover, classification, fixed boundary, LPIS, cadastral parcel

SUMMARY

Within the framework of The European Common Agricultural Policy of the European Union, Agricultural Policy implementation has dramatically changed in the early 1990s with a need of incorporating a vast variety of spatial data and accordingly information systems. Spatial part of these information systems is called as Land Parcel Identification Systems (LPIS). Land use/cover information within these systems is of crucial importance because of the need to monitor farming activities. In Turkey, similar developments and accordingly needs have also been on the agenda since the year 2000. Using cadastre and land registry data, incorporating ortho-photos or imagery and defining physical blocks as land parcel units were three basic alternatives to overcome the problem of both identifying land parcels and assigning their land use/cover information. In addition to the needs of the Ministry of Food, Agriculture and Livestock, emergence of the needs of different institutions (e.g. The Turkish Statistics Institution) has further complicated the properties of required data, especially data on land use/cover information.

In this study, a methodology for the production and updating of Agricultural Land Use/Cover data set was developed and tested in a pilot study area which composed of three districts (Elagoz, Karahoyuk, Vatan) situated in Kocasinan County, Kayseri Province of Turkey. The methodology is essentially based on the delineation of fixed (over years) agricultural land boundaries which may be identified by trees, stones, infertile strip of land or other natural or man-made barriers which lie through boundaries. Agricultural land is classified by five very well defined land use/cover classes of (1) Fertile Land, (2) Planted Agricultural Land, (3) Greenhouses and Fields with Protecting Cover, (4) Meadow and Grassland, (5) Abandoned Agricultural Field, (6) Small Pieces of Infertile Land which is Adjacent to Agricultural Land, (7) Infertile Land, (8) Built-Up Areas and Development Regions. The methodology has been further refined in terms of boundary delineation with support of edge detection algorithms and infrared bands, and also in terms of updating procedures.

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1. INTRODUCTION

The Common Agricultural Policy (CAP) of the European Union has been dependent on Land Parcel Identification Systems (LPIS). Major spatial data content of LPIS are land parcels (cadastral parcels, physical blocs, farmer blocs, agricultural parcels or their combination) and ortho products (ortho imagery or ortho photos) (Kay, 2002; Kay and Milenow, 2006; Inan, 2010; Inan et. al., 2010; Sagris et al, 2013). Classification of land parcels depends on the need and extended use of the system for other purposes and thus vary country by country. In Turkey, similar development has been experienced since the beginning of 2000s (WB, 2005; Goeman et al., 2007; Inan, 2010).

In terms of land use/cover classification in the establishment of LPIS like systems in Turkey, land parcel types (updated only by land owners if required by a land administration or management process) registered in the land registry system were used in the very beginning. Later the need to support the system with spatial land parcel data combined with ortho photo or ortho imagery in order to check land use/cover of land parcels declared to be used for agricultural purposes by farmers, has been raised. Later on, the need by many government institutions (including the Turkish Statistical Institute) or private companies for similar yet complete (in geographical extend, without depending only on declarations by farmers) data (on the amount and type of agricultural land) has come on the agenda.

In this study, within a national project (no 112Y027) financially supported by the Scientific and Technological Research Council of Turkey, a methodology for the production and updating of Agricultural Land Use/Cover data set was developed and tested in a pilot study area which composed of three districts (Elagoz, Karahoyuk, Vatan) situated in Kocasinan County, Kayseri Province of Turkey.

The methodology used in this study is essentially based on the delineation of fixed (over years) agricultural land boundaries which may be identified by trees, stones, infertile strip of land or other natural or man-made barriers which lie through boundaries. To assist in this boundary adjudication process two or more data sets of ortho imagery or ortho photo (ortho images of 2010 and 2013 in this study) were used. Additionally cadastral parcel boundaries were utilised as the supporting evidence (probability of any fixed boundary) in the cases when fixed boundaries were not be able to be delineated without any ambiguity. Agricultural land is classified by five very well defined land use/cover classes of (1) Fertile Land (including fallow land), (2) Planted Agricultural Land (orchard, olive grove, vineyard and other interpretable local trees), (3) Greenhouses and Fields with Protecting Cover, (4) Meadow and Grassland, (5) Abandoned Agricultural Field. Beyond the delineation of fixed agricultural boundary, the methodology incorporates strategies to determine un-fixed boundaries of non agricultural land in three additional classes (6) Small Pieces of Infertile Land which is

Adjacent to Agricultural Land, (7) Infertile Land (rough, hilly, arid land), (8) Built-Up Areas and Development Regions. The methodology has been further refined in terms of boundary delineation with support of edge detection algorithms and infrared bands, and also in terms of updating procedures.

2. THE TERM "FIXED BOUNDARIES"

The term "fixed boundaries" is used in this study for the identification of agricultural field boundaries which remain unchanged over years. Fixed boundaries may be identified by trees, boundary stones, infertile strip of land or other natural or man-made barriers (e.g. roads) which lie through or between boundaries. Samples of digitised fixed boundaries in one of the pilot application areas (Vatan district) are presented in Figure 1. Infertile strip of land larger than 2 m was digitised with its boundaries (see Figure 1-c), narrower ones digitised as a line throung their centerline (see Figure 1-d).

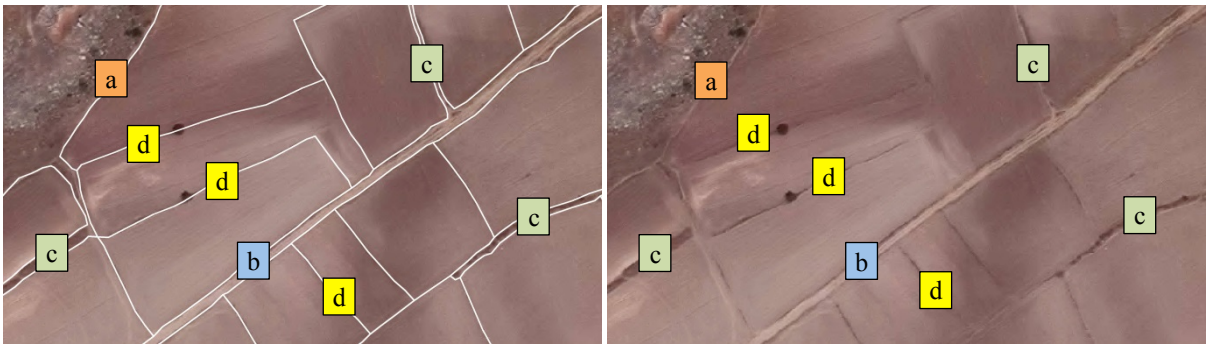

Figure 1. Samples of fixed boundaries (a: infertile land as a natural barrier, b: village road as man-made barrier, c: infertile strip of land wider than 2 meters, d: infertile strip of land narrower than 2 meters) from Vatan district

Thanks to the use of very well defined fixed boundaries approach, a kind of image interpretation standard for the digitisation of agricultural field boundaries precisely was developed. Yet, this standard is only valid and applicable for agricultural field boundaries. For other land use/cover classes this methodology does not apply. So, it has been studied on a different methodology similar to CORINE (EC, 1995) for the digitisation of none-fixed land use/cover class boundaries of none-agricultural land.

3. LAND USE/COVER CLASSIFICATION

Although land use and land cover terms refer theoretically to different objects with different properties on earth surface (Di Gregorio and Jansen, 1998; UN-ECE, 2004; Comber et al., 2005; Inan, 2010), it is not always possible and strictly required to clearly distinguish these two in practice (Inan, 2010; Inan, 2013; Sagris et al., 2013). In the majority of standardisation initiatives (EC, 1995; ISO 19144-2, 2012; INSPIRE D2.8.II.2, 2013) the term land cover are used. Yet, both land use and cover classes are incorporated. In this study, classification of agricultural fields are focussed, and the two terms are combined and called as land use/cover.

3.1 Definition of Land Use/Cover Classes Used in This Study

Fertile: This class includes fertile agricultural land where seasonal crops are cultivated. This class also includes falow land for one or two years. For completely abandoned land for several years another class (abandoned) is designated (see Figure 4). This class is a kind of land use class. In fact it may include a variety of field crops as its land cover. Even in the same piece of fertile land, more than one crop type may simultaneously exist as different subdivisions of land or as different seasonal crops in a year. Fertile lands are completely surrounded by fixed boundaries.

***Planted*:** This class includes agricultural land planted with permanent crops. Fruit orchards, olive groves, vineyards and other interpretable local trees are classified in this class. Depending on type, age, distribution/density of plants/trees, boundaries of such plantation areas are not always easily identifiable. Fixed boundaries around them may be used for boundary adjudication when they are easily visible. Otherwise additional field work may be required.

Protected: Greenhouses and fields with other types of protecting cover are included in this class. Fixed boundaries around them may be used for a general boundary adjudication. Alternatively boundaries of each production unit with a protecting cover may easily be identified.

***Meadow*:** Public meadows and private grassland are included in this class. In the majority of cases boundaries of meadows may not be identified by using the fixed boundaries approach. They may be identified by using land registry record as supporting data. As for personal grassland, they are rare but their boundaries may be identified by using fixed boundaries approach. However, exactly classifying them as meadow is not possible. They may be mixed up with the class Abandoned or Fertile (falow) land. So, truth from the field may be required.

Abandoned: Fields which formerly used as Fertile land and later abandoned. Reasons for such abandonments may be social and economical problems or applications of development plans which may lasts several years in Turkey. In the majority of cases, effects of abandonment on field surface are clearly identifiable. In some cases, they may be mixed up with Fertile (Falow) land or Meadow. So, field truth may be required.

NoneAgricultural: Small pieces or strips of infertile land which are adjacent to, near to or inside Fertile agricultural fields are classified in this class. Such kind of land has the potential to be converted into fertile agricultural land in time. So, changes in such areas should always be monitored. Boundaries of noneAgricultural fields may be fixed or un-fixed depending on their neighbourhood.

Infertile: Roughy, hilly, bushy, woody, infertile arid land etc. are classified in this class. Land in this class is far from agricultural fields and has no potential for the future to be fertile agricultural land. Their boundaries can not be identified by using fixed boundaries approach. By law, such land, in the majority of the cases, is owned by the state. Such land may be classified into many different classes for other purposes. CORINE land cover classes in

second level (see EC, 1995, pp. 21-25) may be used. Because the classification methodology in this study deals only with privately owned land and focusses on agricultural fields with fixed boundaries, further classification has not been studied.

Built-Up: Built-up areas with buildings and planned development regions are included in this class. Boundaries of such areas are not fixed. CORINE methodology for classification level two (see EC, 1995, pp. 21-25) may also be used for further classification. Because the classification methodology in this study focusses on agricultural fields and the fixed boundaries approach, further classification has not been studied.

3.2 Relation with CORINE Land Cover Methodology

Several classes of CORINE land cover methodology and the classes defined with this study are common or have common features. Conversely, the methodology of boundary adjudication and spatial accuracy are different. Yet, exchange of information between the two methodology may be possible in some cases. Classes with similar definitions are listed in Table 1.

Table 1. The relation between Land Use/Cover classes and CORINE land cover

Land Use/Cover Class	**CORINE Equivalent (Level 2)**
Fertile	2.1.Arable land
Planted	2.2. Permanent crops
Protected	---
Meadow	2.3. Pastures
Abandoned	---
NoneAgricultural	---
Infertile	3.3. Open spaces with little or no vegetation
Built-Up	1.1. Urban fabric 1.2. Industrial, commercial and transport units 1.3. Mine, dump and construction sites 1.4. Artificial non-agricultural vegetated areas

4. PRODUCTION OF LAND USE/COVER CLASSES

In the production/digitisation stage of this study, the methodology was essentially based on the delineation of fixed (over years) agricultural land boundaries which can be identified by trees, stones, infertile strip of land or other natural or man-made barriers (see Figure 1 for some examples) which lie through boundaries. To assist in this boundary adjudication process based on the fixed boundaries approach two (or more) data sets of ortho imagery or ortho photo (WorldView2 ortho images of 2010 and 2013 in this study) were used. Using more than one image is not strictly required but increases the ability of exactly adjudicating fixed boundaries which cannot be easily identified on one of the images.

Two different production strategies were adopted and accordingly their methodology were

developed. One is adjudication of all land use/cover boundaries directly on ortho photos or images. The other is subdivision of cadastral land parcels into sub parcels based on land use/cover classes in land parcels. These two approaches may be alternatives or combined for agricultural policy implementations.

A fixed digitisation scale of 1/1000 were used during image interpretation for boundary adjudication and digitisation. In some rare cases, smaller scales were used. Based on previous studies (JRC, 2005; Goeman et al., 2007) on the digitisation of agricultural field boundaries, objects of land use cover narrower than 2 m are neglected and digitised as single line (see Figure 1-d).

4.1 Adjudication of Land Use/Cover Boundaries Directly on Ortho Photos or Images

The order of adjudication/digitisation of boundaries of land use/cover classes is very important in this approach. In this context, boundaries of fertile lands were first digitised, later on, boundaries of other agricultural fields (Planted, Protected and Meadow, Abandoned) were digitised. Boundaries of noneAgricultural fields were digitised in the third round. Exceptionally, strips of noneAgricultural field boundaries were not immediately digitised. A semi-automated digitisation as the fourth stage are proposed for such areas. Yet, the methodology has not completely been applied for the fourth stage. Lastly, boundaries of Infertile and Built-up classes are proposed to be identified and digitised using methodologies similar to CORINE. This stage has not also been applied completely because of focussing on the adjudication of agricultural field boundaries.

In addition to using two different ortho images, cadastral parcel boundaries were utilised as the supporting evidence (probability of any fixed boundaries) for image interpretation in the cases when fixed boundaries were not be able to be delineated without any ambiguity. This approach definitely reduces the need to collect field truth with time consuming field visits. However, the use of cadastral boundaries is not compulsory.

All production/digitisation work in Elagoz, Karahoyuk and Vatan districts for Fertile and Abandoned land use/cover classes were completed. Methodology similar to CORINE has been developed for the digitisation of Infertile and Built-up classes. In fact, these classes may be regarded as out of the scope of this study. However, for the continuity of land use/cover data set, and also for possible use for other purposes, methodology development for these classes is of great importance. Land use/cover objects in Planted, Protected and Meadow classes are rare in application areas. Objects classified in NoneAgricultural class will be digitised with a semi-automatic method, because they are strips of land between Fertile fields in the majority of cases (see Figure 1-c and Figure 3). For Elagoz and Vatan districts, land use/cover data sets both for the years 2010 and 2013 were completed. In Karahoyuk district, land use/cover data set of the year 2010 was only completed (see Figure 2). It seems from the above explanations that the study is incomplete. Yet, in fact, it is estimated that 80% of digitisation and methodology development work has already been completed. Examples of digitised classes are presented in Figure 3 and 4. Examples of digitisation violating the fixed boundaries approach is presented in Figure 5.

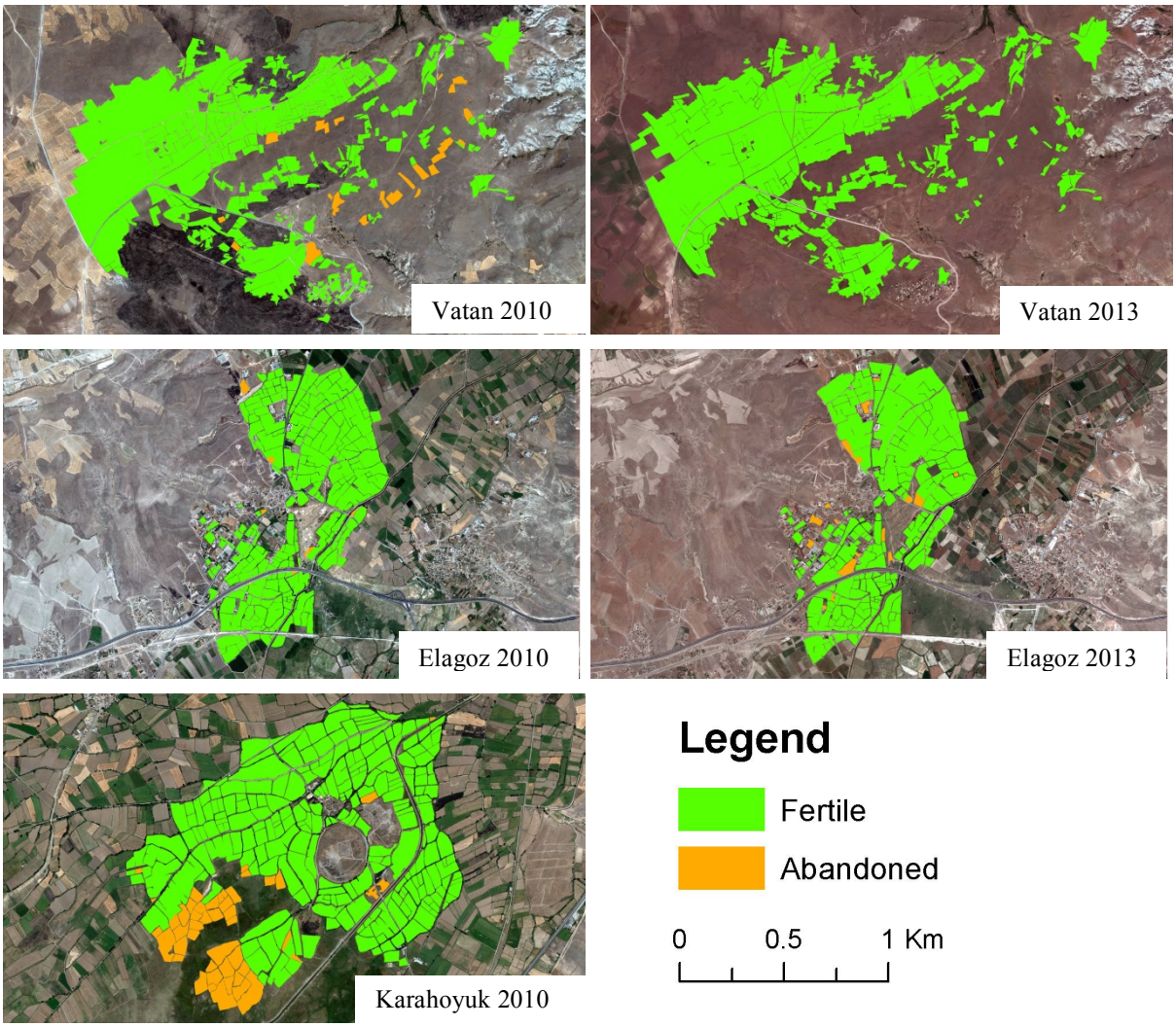

Figure 2. Completed digitisation work for Fertile and Abandoned classes

The partition data structure (no gaps and overlaps) is adopted for land use/cover data sets. Yet, it is not applicable for the current state of the data sets. When all planned digitisation are completed, roads will be as an exception to partition data structure, or alternatively they may be classified as a new land use/cover class (e.g. Road).

Different boundaries between Vatan 2010 and 2013 land use/cover data sets (see Figure 6) do not mean that there were an important change of land use/cover between the years 2010 and 2013. In fact, these differences are caused by abandoned land which may easily be identified/interpreted in 2010 image and may not be identified in 2013 image. The major cause of this situation is that the fixed boundaries methodology does not apply for abandoned land in some cases. This problem should be further studied.

Figure 3. Examples of digitised Fertile land boundaries from Karahoyuk (up) and Vatan (down)

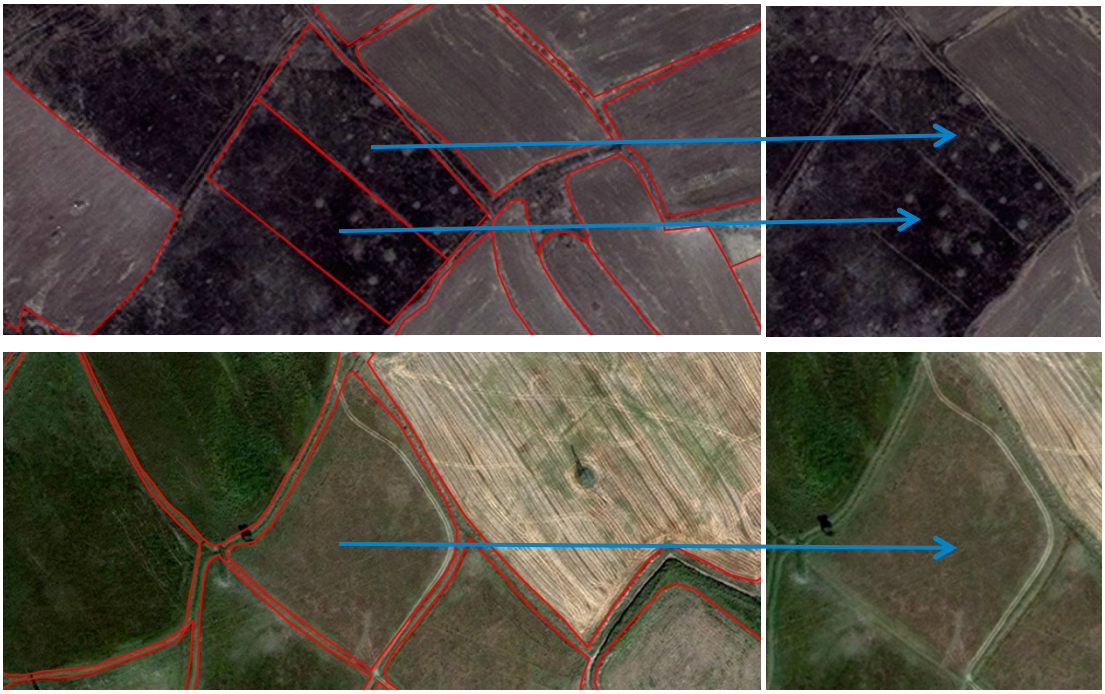

Figure 4. Examples of digitised Abandoned land boundaries from Vatan (up) and Karahoyuk (down)

Figure 5. Examples of boundary digitisation violating to fixed boundaries approach from Elagoz (up) and Karahoyuk (down)

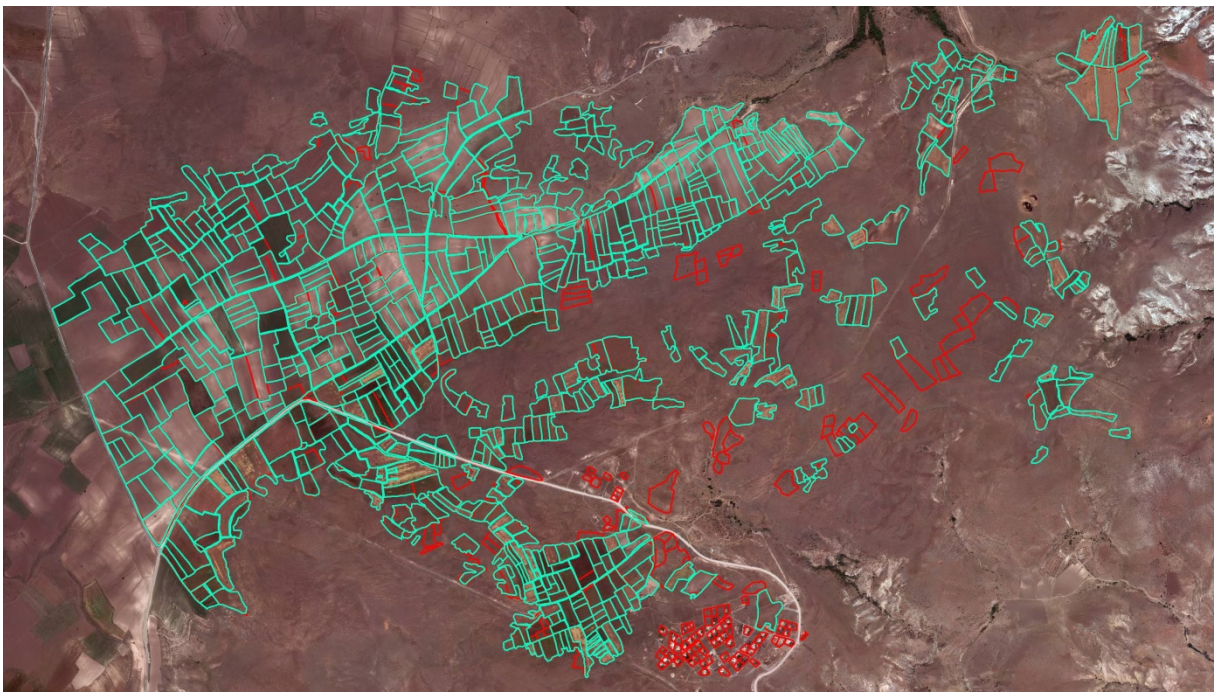

Figure 6. The difference between Vatan 2010 and Vatan 2013 land use/cover boundaries data sets (red ones represent differences)

4.2 Adjudication of Land Use/Cover Boundaries on Cadastral Land Parcels

This methodology suggests the use of cadastral land parcel boundaries together with ortho photos or images as primary data sets in order to produce land use/cover classification data sets. In this context, all land use/cover classes within each land parcel are adjudicated and digitised. This approach is called as sub-parcel data model (Inan, 2008, p.7; Inan, 2010) and each sub parcel is assigned as a land use/cover classification. During the adjudication of sub-parcels the fixed boundaries approach are used. This methodology is a robust solution on the areas subject to private ownership and cadastral registries are readily available. In fact, identification of fixed land use/cover boundaries in land parcels is an easy and appropriate approach when compared with the first methodology (see section 4.1) which is based on adjudication/identification of boundaries on images. Digitisation of land use/cover classes for Vatan, Elagoz and Karahoyuk for the years 2013, 2013 and 2010 respectively (see Figure 7) were completed.

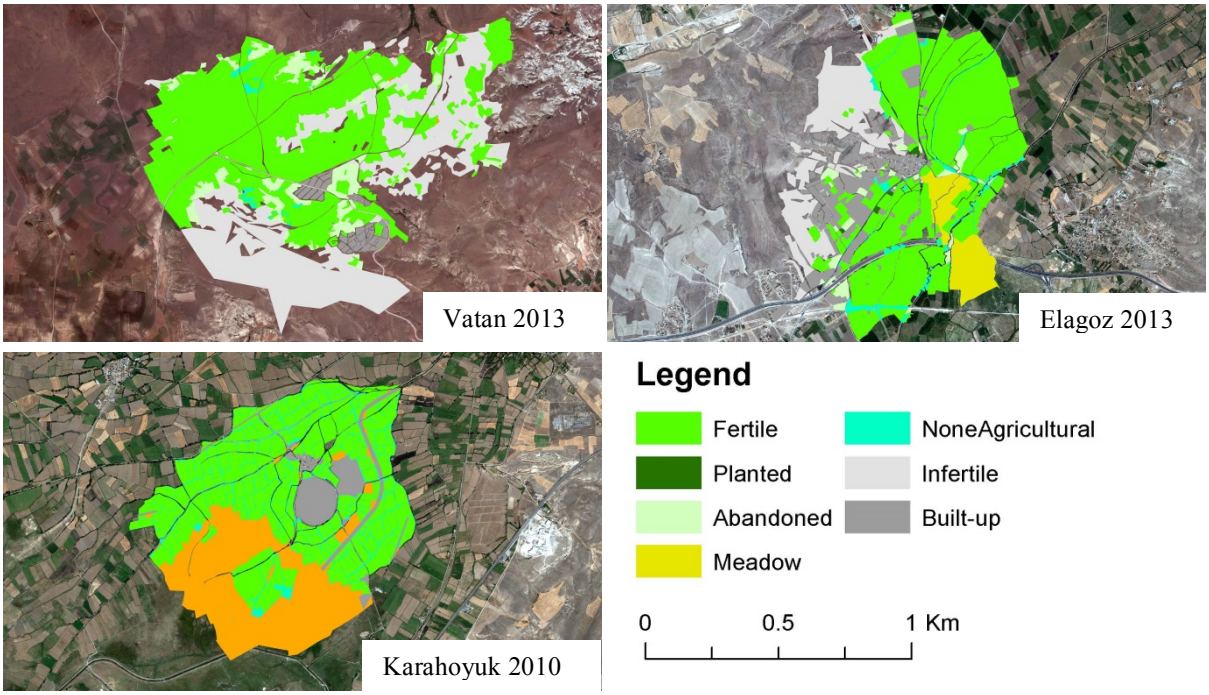

Figure 7. Completed digitisation work for all classes

All boundaries of cadastral parcels are common with the boundaries of sub-parcels. So, all sub-parcel boundaries were not required to be digitised. Samples of sub-parcel boundaries are presented in Figure 8. For Infertile and Built-up classes, boundaries of cadastral parcels and sub parcels are the same in the majority of cases (see Figure 8). Therefore, for an easy digitisation of sub-parcels, cadastral parcel boundaries were replicated and used as raw data for digitisation and classification. Digitisation of strips of infertile land which has a width of at least 2 m as a different land use/cover object in this methodology is not required because, in many cases, cadastral land parcel boundaries go through in the middle of these strips.

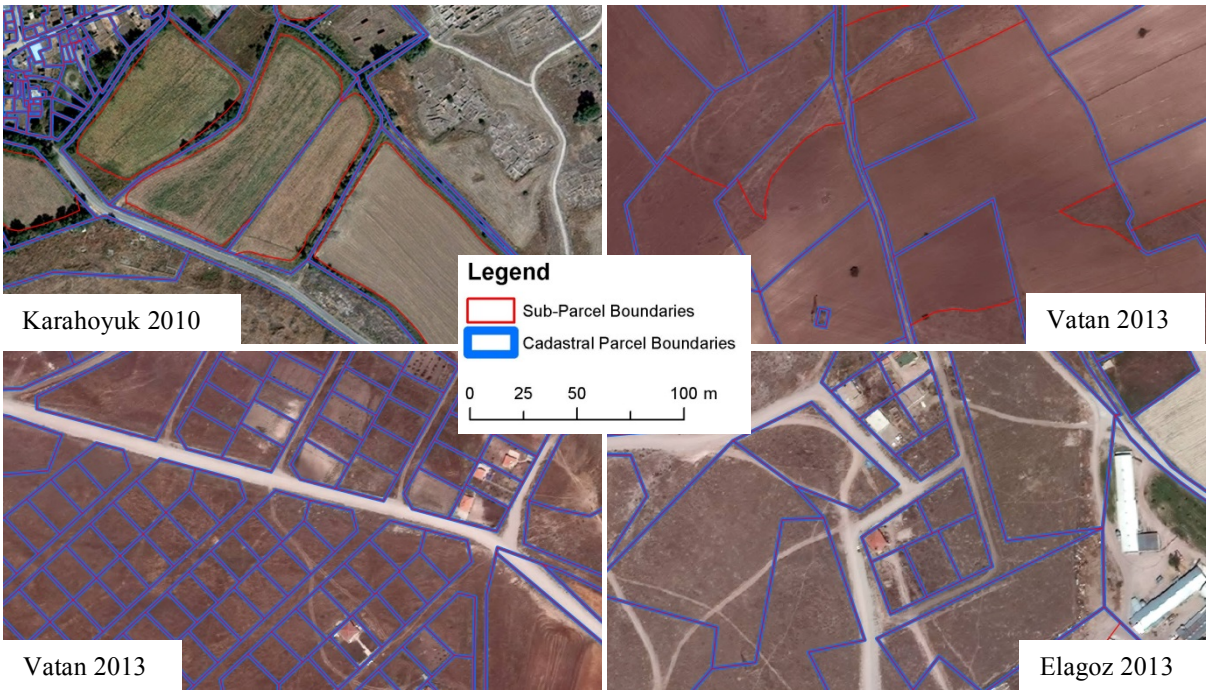

Figure 8. Examples of digitised (or replicated) sub-parcel boundaries. Fertile land subdivided into two or more sub-classes (upper left and right). Infertile land, built-up and development areas without any subdivision.

This methodology has many advantages in boundary adjudication and also for determination of classes. The example of abandoned land boundaries which may not be clearly identified on an ortho image is presented in Figure 9. This example proves that abandoned land boundaries cannot completely be identified directly on ortho images or photos. In fact, depending on the time period of abandonment, boundaries which were formerly fixed changed partially or completely into none fixed boundaries (see Figure 9-left).

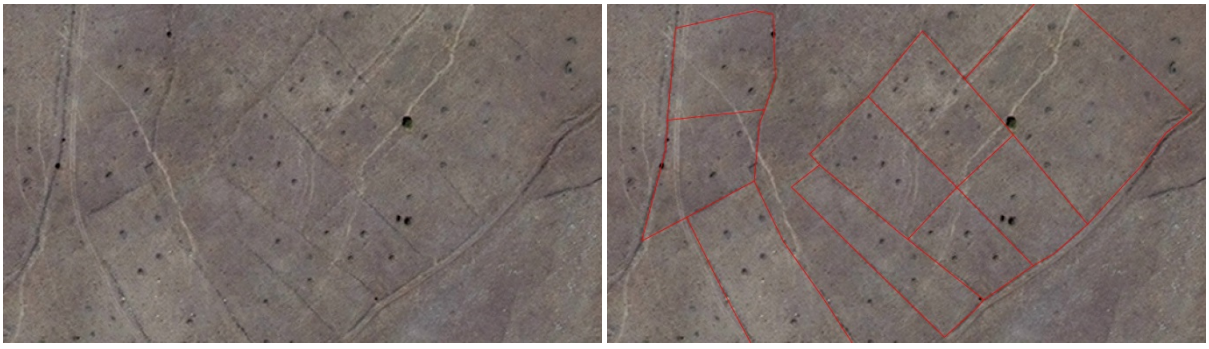

Figure 9. Unclear abandoned land boundaries (left) and replicated cadastral parcel boundaries which match up with abandoned land boundaries (right)

4.3 Updating Procedures

Study on updating procedures has bee continuing. It is evident that continuous monitoring and updating of land use/cover data sets is practically impossible. Update operation have to be dependent on the acquisition of new ortho photos or images. Therefore, change detection algorithms may at first glance be thought to be useful. Yet, differences in acquisition dates and thus image radiometric properties make this approach impossible. It may be carried out on the same kind images taken on the same date (season of year). However, changes in agricultural production pattern may cause problems. In this respect, infrared bands are planned to be used for the determination of green areas. In search for a robust resolution to updating problem, edge detection algorithms are planned to be applied in order to determine changes in boundaries. This method is largely independent from agricultural production seasons. In addition, for updating of sub-parcel boundaries, monitoring changes in cadastral parcels boundaries and accordingly updating sub-parcel boundaries is planned. In fact, this updating methodology is expected to work because changes in cadastral parcel boundaries in rural areas are not common.

5. DISCUSSION AND CONCLUSIONS

The two methodologies presented in this study have some advantages and also dis advantages mutually. Adjudication of land use/cover boundaries directly on ortho photos or images will provide a data set which may commonly used by a variety of users for different purposes. However, except for the adjudication of fertile agricultural land, adjudication procedure is not easily understandable and applicable in the same way by different producers. In fact, in the regions where agricultural land are not common and other land use/cover classes prevail, the digitization work will be harder than the pilot areas of this study. Future study is required in this respect. As for the methodology of adjudication of land use/cover boundaries on cadastral land parcels, it is easy to interpret the boundaries of sub-parcels in the same way by different producers. Yet, it may only used for agricultural policy implementations.

In the case of using the data set produced with the methodology of adjudication of land use/cover boundaries directly on ortho photos or images for agricultural policy implementation, a dissolve operation should be applied in order to refrain from topological errors (raised by Inan 2013) caused by duplication of the same boundary in the two data set (cadastral parcels and land use/cover) digitised/measured differently depending on the different type of data collection techniques (field measurement for cadastral parcel data sets and digitisation on ortho images for land use/cover data set).

Acquisition season/date of images or photos will directly affect the quality of producing/digitising land use/cover boundaries. This truth is partly experienced by using 2010 and 2013 images for pilot areas in this study.

It may be thought that common boundaries between cadastral land parcels and sub-parcels will cause data redundancy. Being aware of this problem, studies on a special data structure has been continuing.

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BIOGRAPHICAL NOTES

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