
Crop Monitoring as an
E-agricultural tool in
Developing Countries


# GROUND SAMPLING AND DATA COLLECTION

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# LIST OF ACRONYMS

| | |
|---|---|
| AFS | Area Frame Sampling |
| GPS | Global Position System |
| CV | Coefficient of variation of population total estimator |

# TABLE OF CONTENT

# LIST OF FIGURES

# LIST OF TABLES

# EXECUTIVE SUMMARY

The first objective of the work-package D51.1 aims to adapt and design the segment sampling methods and collect the ground samples using these adapted methods. The ground sampling approach on the Huaibei Plain was investigated by establishing the study area in the county of Mengcheng for the first year of implementation and in the county of Guoyang for the second year of implementation. This deliverable describes the two approaches used to adapt the grounds sampling method and more specifically the way with which the segment sample data are collected. The deliverable contains also an analysis of the samples included in the databases. The approaches that we finally adopted are results of an extensive discussion between partners of the E-AGRI consortium, especially with the Joint Research Centre of the Commission.

# 1 INTRODUCTION

The objective of this study is to estimate the crop acreages on county level in Huaibei Plain using ground sampling database combined with remote sensing data. According to the targets, two counties in Anhui province, Mengcheng and Guoyang, were chosen for the study area (Figure 1.1), and the following three aspects had been conducted: collection of background data, design and implementation of segment sampling method, establishment and assessment the spatial model. This deliverables focuses on the approaches with which the samples are collected.

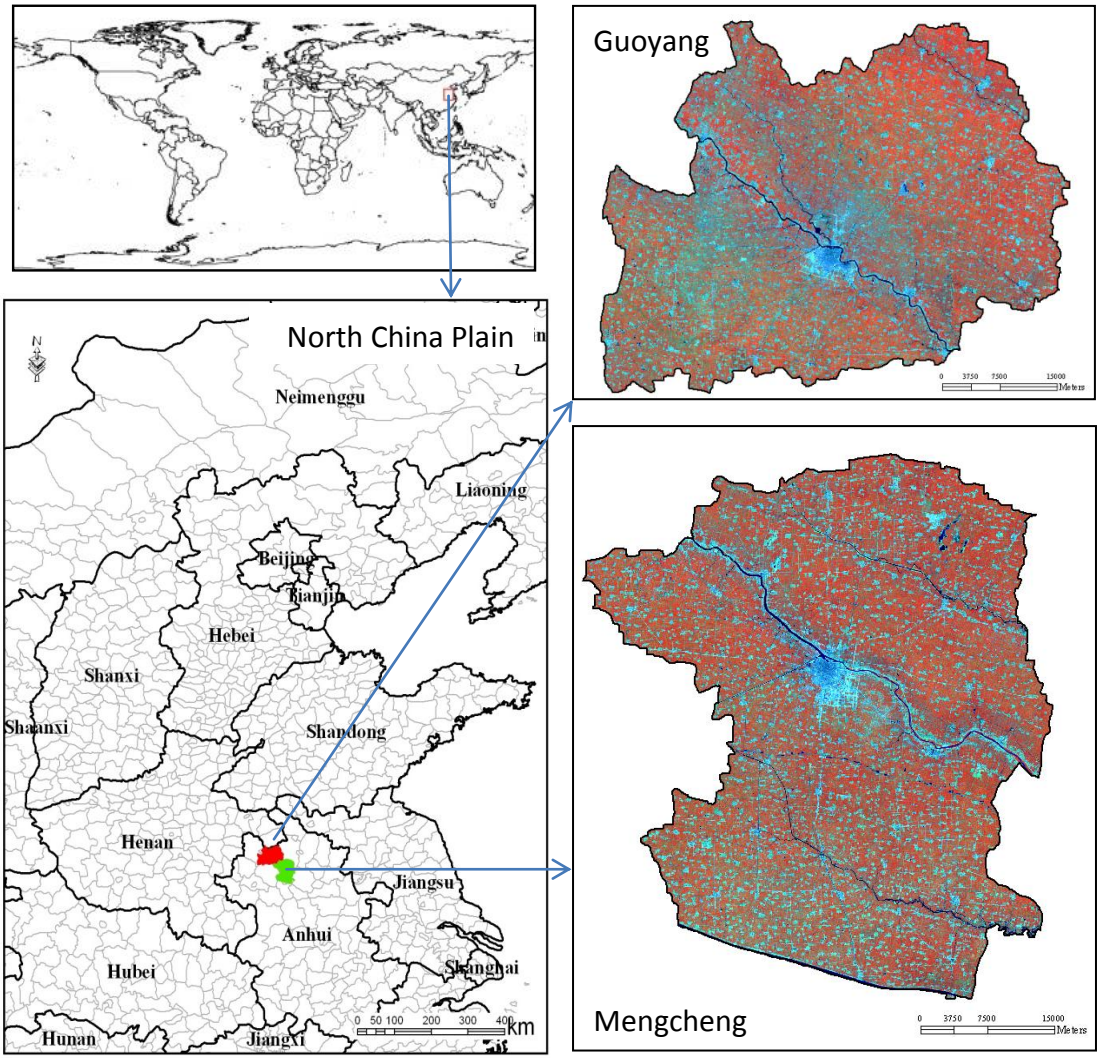



***Figure 1. 1 The study area***

Mengcheng and Guoyang are located at the east of Bozhou City, north of Anhui province, south of Huang-Huai plain, hinterland of Huaibei plain. They belongs to a temperate and semi-humid monsoon climate zone, located at transitional zone between northern subtropical and warm temperate zone, featured with notable alternate wetting and drying climate, humid and hot in summer, dry and cold in winter.

Mengcheng County is ranging between N 32°55' - 32°30', and E 116°15' - 116°50'. The shape of Mengcheng County is slightly rectangular, extending 40 km from east to west, and 60 km from north to south. It has a population of 1,320,000 inhabitants and an area of 214,880 ha. The climate in Mengcheng county can be described as warm temperate semi-humid monsoon type, with an annual average temperature of 14.7°C, the annual average frost-free period 216 days, the average annual precipitation of 822 mm. With a fertile soil, a mild climate and a moderate rainfall, the crop production including wheat, rice, maize and potato are of high-quality.

Guoyang County is ranging between N 33°27' - 33°47', and E 115°53' - 116°33', with a total area of 2107 $km^2$. Governed by an annual average temperature of 14.6C°, frost free period of 218 days and average annual precipitation about 830mm, the region is wealthy in terms of light, heat and reasonable water resources. As its maximum precipitation and highest temperature occur in the same period of season, the climate is favourable for the growth of dry crops such as wheat, soybean, maize, sweet potato, and etc. In 2010, the crop planting area of the county was 267,000 hectares, with grain sown area of 241,000 hectares, including wheat 118,000 hectares, maize 40,000 hectares and soybeans 75,000 hectares. Guoyang County is one of national grain commodity production bases.

# 2 SEGMENT SAMPLING DATABASE

## 2.1 Collection of background data

Background data includes the statistical crop area of recent 10 years, crop phenology data and ancillary geographic data, such as boundary of administrative units and road map, were collected.

### 2.1.1 Statistical data of crop area

The crop area statistical data for whole Anhui Province from 2000 to 2011 were collected, including agricultural productions (grain, cotton, oil-bearing crops), and cultivated area (paddy field, total sown area, and area of orchards, etc. Table 2.1 lists the categories of data which were collected. For the categories such as grain yields, sown areas and area of orchards, the data was grouped by county. For other fields, the data was grouped by prefecture. In 2009, there were 17 prefectures including 105 counties.

***Table 2.1 The fields of the collected statistical data in Anhui province from 2000-2011***

| Fields (area) | Fields (area) | Fields (area) |
|---|---|---|
| total sown area | sown area of grain crops | cereal |
| rice | wheat | maize |
| soybean | tubers | oil-bearing crops |
| peanuts | rapeseed | sesame |
| cotton | fibre crops | sugar crops |
| tobacco leaf | medicinal materials | vegetables |
| melon | area of tea plantations at year-end | area of orchards at year-end |
| medicinal materials | vegetables | |

Figure 2.1 shows crop production and acreage in Anhui province. Figure 2.2 displays the variation of total sown area from 2000 to 2011 in Anhui Province. In recent year, the total sown area tends to be stable around 9,000,000 ha.

| 县（市） | County（City） | 粮食(吨) Grain(ton) | 棉花(吨) Cotton(ton) | 油料(吨) Oil-bearing Crops(ton) | 耕地面积(公顷) Cultivated Area(hectares) | #水田 PaddyField( hectares) | 播种面积(公顷) Total Sown Area(hectares) | 果园面积(公顷)Area of Orchards | 农作物播种面积 Total Sown Area | 粮食作物播种面积 Sown Area of Grain Crops | #谷物Cereal | ##稻谷Rice | ##小麦Wheat | ##玉米Corn | #豆类Soy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 全省合计 | Total | | | | | | | | 9009851 | 6603295 | 5605006 | 2338578 | 2466017 | 777947 | |
| 合肥市 | Hefei | | | | | | | | 497410 | 278363 | 265578 | 139437 | 52825 | 10859 | |
| 合肥市辖区 | Hefei Region of City | 74261 | 782 | 11768 | 11700 | 9062 | 26693 | 366 | | | | | | | |
| 长丰县 | Changfeng | 606143 | 5859 | 69279 | 67562 | 51052 | 146600 | 367 | | | | | | | |
| 肥东县 | Feidong | 671716 | 4784 | 139082 | 79888 | 60867 | 182072 | 476 | | | | | | | |
| 肥西县 | Feixi | 551900 | 7461 | 97146 | 60323 | 48672 | 142045 | 838 | | | | | | | |
| 淮北市 | Huaibei | | | | | | | | 284593 | 260122 | 165970 | 381 | 123101 | 39575 | |
| 淮北市辖区 | Huaibei Region of City | 220289 | 773 | 2078 | 24947 | 293 | 59726 | 5118 | | | | | | | |
| 濉溪县 | Suixi | 986912 | 3280 | 8491 | 111002 | 0 | 224867 | 104 | | | | | | | |
| 亳州市 | Bozhou | | | | | | | | 1017034 | 843933 | 600997 | 3093 | 415619 | 178204 | |
| 亳州市辖区 | Bozhou Region of City | 854670 | 13074 | 7742 | 126984 | 0 | 260149 | 806 | | | | | | | |
| 涡阳县 | Guoyang | 1274167 | 2019 | 7532 | 131146 | 0 | 276244 | 193 | | | | | | | |
| 蒙城县 | Mengcheng | 1248927 | 4280 | 24396 | 122306 | 978 | 244928 | 385 | | | | | | | |
| 利辛县 | Lixin | 1102437 | 1338 | 7352 | 116819 | 2607 | 235713 | 108 | | | | | | | |
| 宿州市 | Suzhou | | | | | | | | 980417 | 776997 | 588170 | 8101 | 378368 | 200167 | |
| 宿州市辖区 | Suzhou Region of City | 1096414 | 9087 | 36943 | 141855 | 548 | 279553 | 4359 | | | | | | | |
| 砀山县 | Dangshan | 255805 | 5306 | 36623 | 37273 | 0 | 97043 | 48010 | | | | | | | |
| 萧县 | Xiaoxian | 696748 | 13537 | 20273 | 91890 | 65 | 183683 | 6235 | | | | | | | |
| 灵璧县 | Lingbi | 962925 | 4365 | 60865 | 120171 | 2021 | 230048 | 1108 | | | | | | | |
| 泗县 | Sixian | 787995 | 7503 | 67232 | 88332 | 5227 | 190090 | 40 | | | | | | | |
| 蚌埠市 | Bengbu | | | | | | | | | | | | | | |
| 蚌埠市辖区 | Bengbu Region of City | 181712 | 193 | 2727 | 22008 | 12929 | 47551 | 475 | 635766 | 468294 | 408447 | 106283 | 239179 | 61543 | |
| 怀远县 | Huaiyuan | 1208947 | 6372 | 72663 | 126745 | 52264 | 257073 | 1662 | | | | | | | |
| 五河县 | Wuhe | 775193 | 3405 | 61061 | 71475 | 36765 | 177464 | 869 | | | | | | | |
| 固镇县 | Guzhen | 478234 | 19299 | 161338 | 70532 | 1723 | 153678 | 486 | | | | | | | |
| 阜阳市 | Fuyang | | | | | | | | 1210534 | 987186 | 764505 | 51440 | 498787 | 205158 | |
| 阜阳市辖区 | Fuyang Region of City | 883724 | 2897 | 16519 | 105404 | 35 | 221210 | 948 | | | | | | | |
| 界首市 | Jieshou | 373011 | 2503 | 6384 | 38860 | 0 | 84417 | 535 | | | | | | | |
| 临泉县 | Lingquan | 1056996 | 5065 | 21436 | 113580 | 1316 | 253218 | 780 | | | | | | | |
| 太和县 | Taihe | 950466 | 3038 | 9123 | 115580 | 0 | 231297 | 325 | | | | | | | |
| 阜南县 | Funan | 846920 | 1819 | 25247 | 97792 | 17359 | 205316 | 213 | | | | | | | |
| 颍上县 | Yingshan | 1043671 | 4159 | 8449 | 103273 | 37049 | 215076 | 297 | | | | | | | |
| 淮南市 | Huainan | | | | | | | | 245074 | 210124 | 197019 | 92498 | 101448 | 2396 | |
| 淮南市辖区 | Huainan Region of City | 663771 | 1268 | 10406 | 58386 | 40221 | 128502 | 775 | | | | | | | |
| 凤台县 | Fengtai | 587686 | 470 | 5069 | 45981 | 32487 | 96331 | 647 | | | | | | | |
| 毛集区 | Maoji District | 118685 | 32 | 915 | 9905 | 6520 | 20241 | 19 | | | | | | | |
| 滁州市 | Chuzhou | | | | | | | | 855730 | 681234 | 649022 | 340641 | 286551 | 31038 | |
| 滁州市辖区 | Chuzhou Region of City | 300832 | 2731 | 25033 | 27989 | 22458 | 73124 | 757 | | | | | | | |
| 天长市 | Tianchang | 689168 | 16 | 24189 | 58940 | 57821 | 118893 | 7 | | | | | | | |
| 明光市 | Mingguang | 537916 | 505 | 26776 | 55533 | 26931 | 123406 | 738 | | | | | | | |
| 来安县 | Lianan | 442991 | 268 | 38684 | 46512 | 35874 | 95594 | 648 | | | | | | | |
| 全椒县 | Quanjiao | 431656 | 5329 | 60657 | 40454 | 29299 | 87832 | 217 | | | | | | | |
| 定远县 | Dingyuan | 1116104 | 1258 | 39813 | 101946 | 74553 | 212305 | 639 | | | | | | | |
| 凤阳县 | Fengyang | 716424 | 608 | 18944 | 66768 | 38400 | 144576 | 1108 | | | | | | | |
| 六安市 | Luan | | | | | | | | 881402 | 675616 | 648845 | 411518 | 214570 | 21711 | |
| 六安市辖区 | Luan Region of City | 838992 | 5274 | 74557 | 94127 | 80393 | 206921 | 654 | | | | | | | |
| 寿县 | Shouxian | 1413689 | 4162 | 55609 | 121420 | 105462 | 244591 | 290 | | | | | | | |

全省县以上行政区划 / 2000年 / 2001年 / 2002年 / 2003年 / 2004年 / 2005年 / 2006年 / 2007年 / 2008年 / 2009年

***Figure 2. 1 Crop-specific crop production and acreage in Anhui (prefecture 2000-2011)***

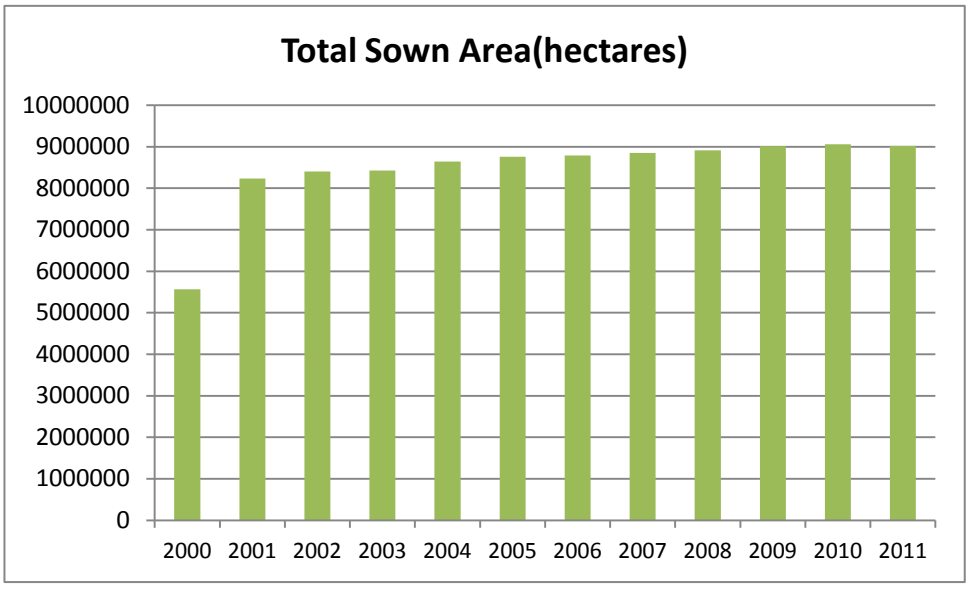



***Figure 2. 2 The variation of total sown area in Anhui Province from 2000 to 2011***

Mengcheng and Guoyang belong to Bozhou City. There are six counties in Bozhou, they are Bozhou Region of City, Qiaocheng District, Guoyang county, Mengcheng county, Lixin city, and Development District. Before 2006, there were five counties in Bouzhou City. But in the end of 2005, a new zone, Development District, was independent out Qiaocheng District. In order to compare with other data, we collected the statistics data of all counties of Bozhou at the same time. The data was from 1999-2010 and were grouped by county, including 23 fields such as total

sown area, sown area of grain crops, cereal, rice, wheat, maize, soybean, tubers, bearing crops, peanuts, rapeseeds, sesame, cotton, fibre crops, sugar crops, tobacco leaf, medicinal materials, vegetables, area of tea plantations at year-end, area of orchards at year-end, medicinal materials, vegetables and melon. The data came from Bozhou Statistical Yearbook. Table2.2 to 2.4 show the change of main crop area of Bozhou, including winter wheat, soybean and maize from 1999 to 2010.

***Table 2.2 Statistical data of winter wheat area from 1999 to 2010*** (unit: hectares)

| County | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bozhou Region of City** | 345543 | 325926 | 311040 | 306705 | 299758 | 337366 | 361370 | 371779 | 391181 | 406372 | 415619 | 418356 |
| **Qiaocheng District** | 76447 | 67624 | 59781 | 62777 | 61787 | 63621 | 73782 | 73599 | 81897 | 82382 | 85444 | 86871 |
| **Guoyang** | 91819 | 91279 | 91993 | 89022 | 89903 | 96867 | 103847 | 109762 | 112206 | 116752 | 118574 | 118092 |
| **Mengcheng** | 88837 | 78088 | 73714 | 68445 | 68190 | 92359 | 94081 | 96256 | 98731 | 103420 | 107394 | 108438 |
| **Lixin** | 88440 | 88935 | 85552 | 86461 | 79878 | 84519 | 89660 | 92030 | 98174 | 103674 | 104092 | 104835 |
| **Development District** | | | | | | | | 132 | 173 | 144 | 115 | 120 |

***Table 2.3 Statistical data of soybean area from 1999 to 2010*** (unit: hectares)

| County | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bozhou Region of City** | 104048 | 110925 | 117134 | 128235 | 146727 | 176702 | 218511 | 238431 | 278947 | 240758 | 224471 | 212151 |
| **Qiaocheng District** | 20353 | 22397 | 21235 | 21720 | 24792 | 26988 | 37868 | 39479 | 47438 | 40337 | 43873 | 51238 |
| **Guoyang** | 39924 | 44433 | 48108 | 52469 | 60244 | 69999 | 84902 | 93352 | 113409 | 95397 | 84248 | 75726 |
| **Mengcheng** | 13154 | 13374 | 15418 | 15092 | 18122 | 24777 | 31139 | 35349 | 34170 | 36356 | 32306 | 24073 |
| **Lixin** | 30617 | 30721 | 32373 | 38954 | 43569 | 54938 | 64602 | 70211 | 83869 | 68630 | 63975 | 61069 |
| **Development District** | | | | | | | | 40 | 61 | 38 | 69 | 45 |

***Table 2.4 Statistical data of maize area from 1999 to 2010*** (unit: hectares)

| County | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bozhou Region of City** | 123006 | 93581 | 105317 | 113633 | 113211 | 106634 | 102610 | 101307 | 138153 | 135362 | 176204 | 182196 |
| **Qiaocheng District** | 33462 | 23327 | 23477 | 26155 | 24161 | 24446 | 23254 | 23928 | 28713 | 23166 | 27820 | 28752 |
| **Guoyang** | 27517 | 25581 | 30614 | 32472 | 30405 | 26500 | 21147 | 19904 | 24668 | 25384 | 38733 | 40032 |
| **Mengcheng** | 34107 | 21847 | 25840 | 27448 | 27976 | 26749 | 31238 | 31597 | 53627 | 55196 | 68202 | 70514 |
| **Lixin** | 27920 | 22826 | 25386 | 27558 | 30669 | 28939 | 26971 | 25797 | 31055 | 31559 | 41391 | 42789 |
| **Development District** | | | | | | | | 81 | 90 | 57 | 58 | 109 |

As shown by Figure 2.3 below, from 1999 to 2010, the area of main crops of Mengcheng County were unstable. From 2004, the area of winter wheat and maize were slowly increasing, especially the maize area. Figure 2.4 shows the crop area variation of Guoyang County. From 1999 to 2010, the winter wheat area was slowly increase from 8900ha to 11800ha, and remained relatively stable in the last three years. However, relatively large change occurred in the area of soybean an maize.

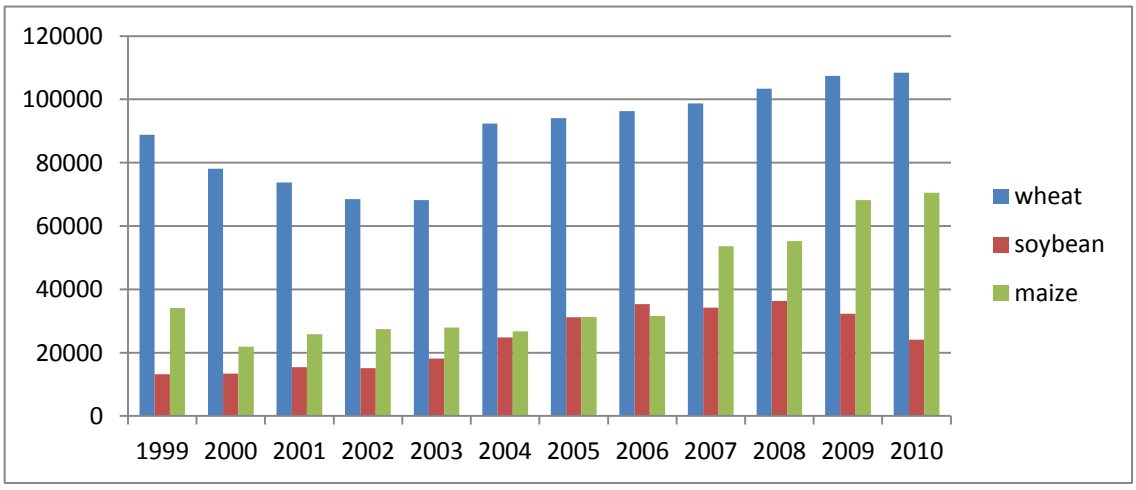



***Figure 2. 3 The main crop area of Mengcheng County from 1999 to 2010***

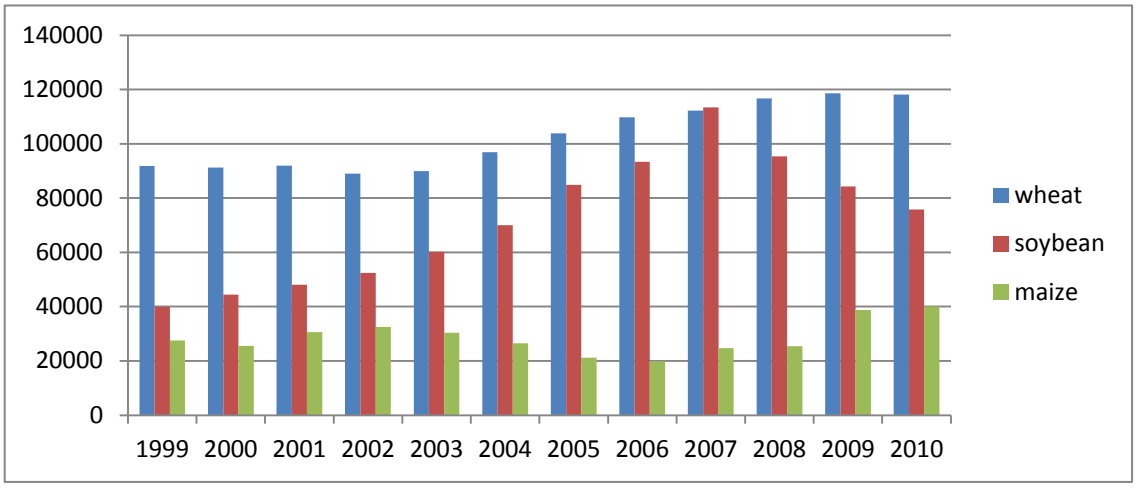



***Figure 2. 4 The main crop area of Guoyang County from 1999 to 2010***

### 2.1.1.1 Mengcheng County

The global objective is to estimate the 2011 acreages of maize and soybean of the Mengcheng County using field survey combined with high resolution remote sensing data. The monitored crops are wheat in winter and maize and soybean during this summer season (Table 2.5).

***Table 2.5 Official statistics on crop areas in Mengcheng (hectare)***

| Crop /growth season | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|
| Rice **(all year)** | 1,400 | 881 | 1,215 | 2552 |
| Wheat **(winter-spring)** | 98,731 | 103,420 | 107,394 | 108438 |
| Maize **(summer)** | 53,627 | 55,196 | 68,202 | 70514 |
| soybeans **(summer)** | 34,170 | 36,356 | 32,306 | 24073 |
| Potato/Sweet potato **(summer)** | 7,312 | 4,360 | 5,171 | 12035 |
| Peanut **(summer)** | 7,675 | 9,262 | 4,262 | 4614 |
| Rape **(winter-spring)** | 1,097 | 839 | 570 | 482 |
| Sesame **(summer)** | 2,449 | 1,768 | 1,019 | 673 |
| Cotton **(spring-summer)** | 11,991 | 10,006 | 4,141 | 5209 |
| Medicinal herbs **(all year)** | 844 | 646 | 454 | 1606 |
| Vegetables **(all year)** | 20,248 | 16,302 | 15,088 | 15332 |
| Cultivated Arable land **(spring)** | 132,911 | 131,213 | 127,655 | 131067 |
| Cultivated Arable land **(summer)** | 139,716 | 134,777 | 131,866 | 136608 |

The official statistics were collected at level of county. As shown by Figure2.5 below, maize has covered an increased part of the county total area from 25% in 2007 to 34% in 2010 whereas soybean tends to be stable around 34,000 ha. The unpublished official statistics showed an area of 100,000 hectares for the maize sowing area in 2011.

However this might be an underestimated figures as the statistical data at county level are not entirely reliable. A possible explanation to this underestimation is that the official figure of arable land does not include the river bed areas which are now cultivated by farmers. These river beds might increase the official figure of up to 20%.

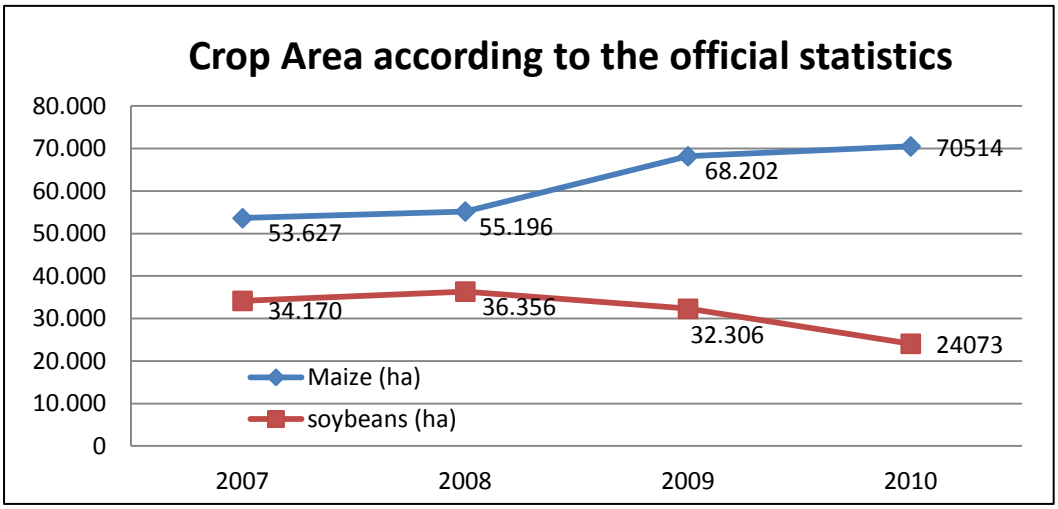



***Figure 2. 5 Maize and Soybean crop area according to the official statistics of Mengcheng county for 2007-2010***

### 2.1.1.2 Guoyang County

The global objective is to estimate the 2012 acreages of winter wheat and maize and soybean of the Guoyang County using ground sampling units . According to the official statistics, the main cultivations are wheat in winter and soybean during the summer (Table 2.5). Figure 2.6 shows the the official statistics data of main crop area for 2007-2010.

*Table 2.6 Crop areas (Mengcheng official statistics)*

| Crop /growth season | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|
| Rice **(all year)** | | | | |
| Wheat **(winter-spring)** | 112206 | 116752 | 118574 | 118092 |
| Maize **(summer)** | 24668 | 25384 | 38733 | 40032 |
| soybeans **(summer)** | 113409 | 95397 | 84248 | 75726 |
| Potato/Sweet potato **(summer)** | 3301 | 2789 | 4613 | 5779 |
| Peanut **(summer)** | 923 | 990 | 851 | 609 |
| Rape **(winter-spring)** | 1031 | 693 | 599 | 395 |
| Sesame **(summer)** | 3496 | 3306 | 2671 | 1275 |
| Cotton **(spring-summer)** | 4021 | 3250 | 1906 | 1638 |
| Medicinal herbs **(all year)** | 2990 | 2716 | 2766 | 3010 |
| Vegetables **(all year)** | 16743 | 16806 | 16988 | 17469 |
| Cultivated Arable land **(spring)** | 16743 | 16806 | 16988 | 17469 |
| Cultivated Arable land **(summer)** | 136991 | 140217 | 140833 | 140604 |

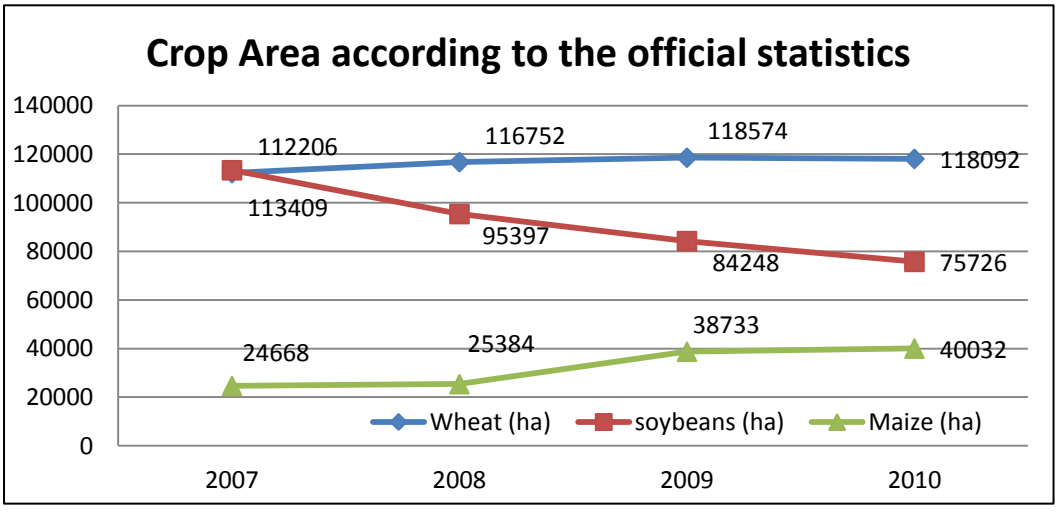



***Figure 2. 6 Winter wheat and maize and soybean crop area according to the official statistics of Guoyang county for 2007-2010***

### 2.1.2 Crop phenology data

Phenology data of typical crops were collected and sorted in two tables. The first table (Table2.7) lists the crop phenological phase in accordance of chronological order. The temporal resolution was month and all 12 months in a year were covered, including the major periods of sowing, seedling emergence and harvesting of the four staple crops. The second one (Table2.9-2.10) lists the phenol-phase of crop in accordance of crop growth period.

***Table 2.7 Annual Crop Growth and Development***

| Date | Crop | Growth Stage |
|---|---|---|
| **From December to February** | Winter wheat | Slow growth stage, ear differentiation |
| | Rape | Coming into leaf, budding, and bolting |
| **March** | Winter wheat | Jointing |
| | Rape | Budding, bloom |
| **April** | Winter wheat | Heading and bloom, grain filling and milk ripeness in the last third of the month |
| | Rape | Bloom, scab |
| | Cotton | Seeding |
| **May** | Winter wheat | Milk ripeness, ripeness, harvesting |
| | Rape | Ripeness, harvesting |
| | One-season rice | Seeding, raising rice seedlings |
| **June** | Winter wheat | Finishing harvesting within the first third of this month |
| | Maize | Seeding |
| | Cotton | Budding |
| | One-season rice | Transplant, reviving, tiller |
| **July** | Maize | Tasseling, bloom |
| | Cotton | Bloom |
| | One-season rice | Jointing, heading, bloom |
| **August** | Maize | Grain filling, milky ripeness |
| | Cotton | Bloom, splitting boll |

| Date | Crop | Growth Stage |
|---|---|---|
| | One-season rice | Bloom, milk ripeness |
| **September** | Rape | Seeding |
| | Maize | Ripeness, harvesting |
| | Cotton | Opening bolls, picking up cottons |
| | One-season rice | Milk ripeness, ripeness, harvesting |
| **October** | Winter wheat | Seeding |
| | Rape | Emergency of seedlings |
| **November** | Winter wheat | Emergency of seedlings, tiller |
| | Rape | In the fifth euphylla, transplant |

***Table 2.8 Winter wheat growth and development process***

| Crop | Sowing stage | Tillering stage | Overwintering | Reviving | Jointing stage | Heading | Maturation period |
|---|---|---|---|---|---|---|---|
| **Winter wheat** | later October – early November | early December | | | later February early March | early April | later May/– June/early |

***Table 2.9 Single-season rice growth and development process***

| Crop | Sowing stage | Full heading stage | Maturation period |
|---|---|---|---|
| One-season Rice(indica type ) | Late March- Early April | Mid September – Early October | End October- Early November |
| One-season Rice (japonica type) | End March- Mid. April | Early September- Late September | Early October- Mid. October |

***Table 2.10 Maize growth and development***

| Crop | Seeding-emergence of seedling | Emergence of seedling-jointing | Jointing -Heading | Heading-grain filling | Harvesting |
|---|---|---|---|---|---|
| Spring maize | later April - later May | later May -early June | early July & middle | August early | later August - early September |
| Summer maize | middle June - later June | | Early August | | later September |

### 2.1.3 Ancillary geographic data

The boundary of administrative units and road map were collected.

The boundary of administrative units was download from http://ngcc.sbsm.gov.cn/. The information of administrative division of three levels of province, regions (shi) and counties by the end of 2009. The results show that Anhui Province has 17 district-level shi and 106 counties.

Figure 2.7 shows the administrative units of Anhui.

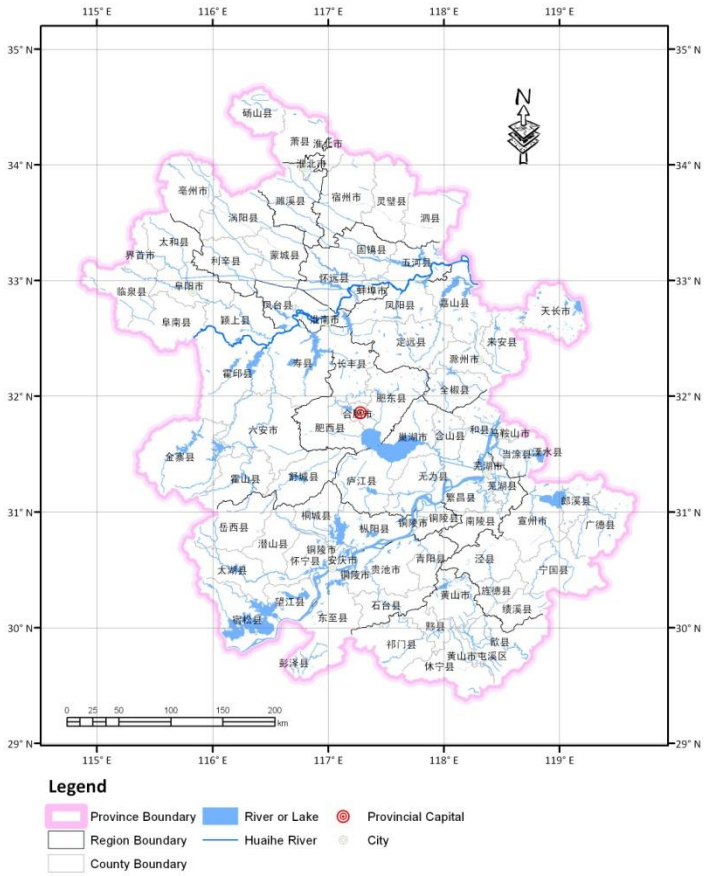



***Figure 2. 7 Administrative regions in Anhui Province***

The road map of Guoyang County was extracted from the Rapideye images by visual interpretation ( Figure2.8). It was used for the result correction of hard classification. For other counties, the road map was download from http://ngcc.sbsm.gov.cn/.

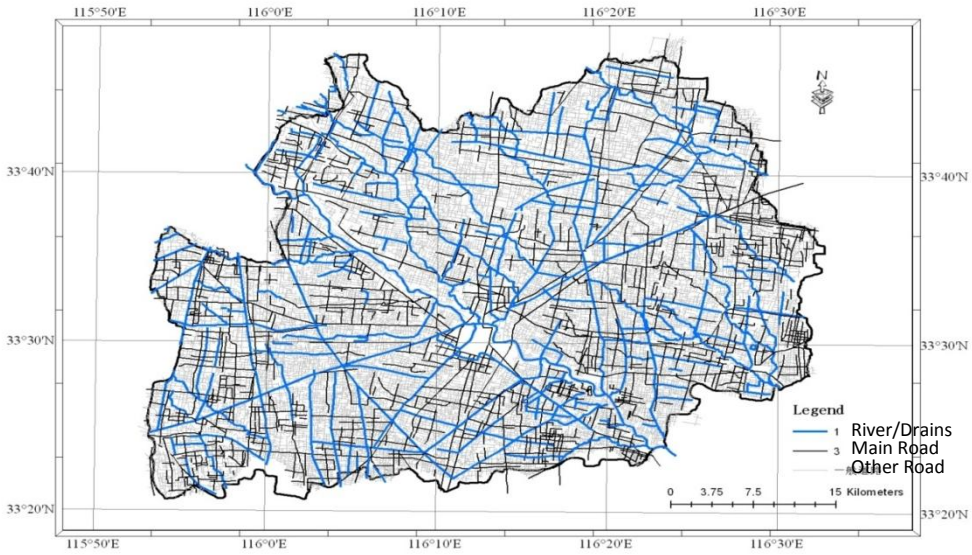



*Figure 2. 8 Road map of Guoyang county*

## 2.2 Design of Ground Sampling Units

In order to find the best way to estimate the acreage of the main crops on county level using ground sampling database, different sampling methods were used to design the ground sampling units of Mengcheng and Guoyang. For Mengcheng County, the gound sampling units were physical boundaries, and the area of each unit was different. For Guoyang County, sampling units were designed based on systematic sampling method. All units were circle boundaries, and the area of each unit was same.

### 2.2.1 Mengcheng County

For Mengcheng County, we designed two types of the Ground sampling units. One type was used for the establishment of the crop area spatial extrapolation model. The other type was used for interpretation signs and validation data.

#### 2.2.1.1 The Ground sampling units for the spatial extrapolation

In order to assess the area of the main crops of the Mengcheng County, an Area Frame Sampling (AFS) scheme based on segments with physical boundaries was derived. The strategy was to survey in the field 100 segments randomly selected in the arable stratum during the cropping season in order to determine the proportions of the various crops (mainly maize and soybean at the time of the survey).

To determine the importance of the various strata (mainly arable land and non-agricultural land as no permanent crops were found in the county) and identify the arable stratum before the

survey, a grid of points was interpreted on Google Earth (GE) Very High Resolution (VHR) imagery. All the points in the grid are stratify using photo-interpretation. 100 arable points were selected and the corresponding segments were built around these points through the physical boundaries on GE imagery.

In practice, the stratification was based on a grid of 532 points located every 2 km while the selection of the segment points was made from 4 km grids (called grid A and grid B), i.e. subsets of the 2 km one, in order to have a regular distribution of the segments in the county (Figure 2. 9).

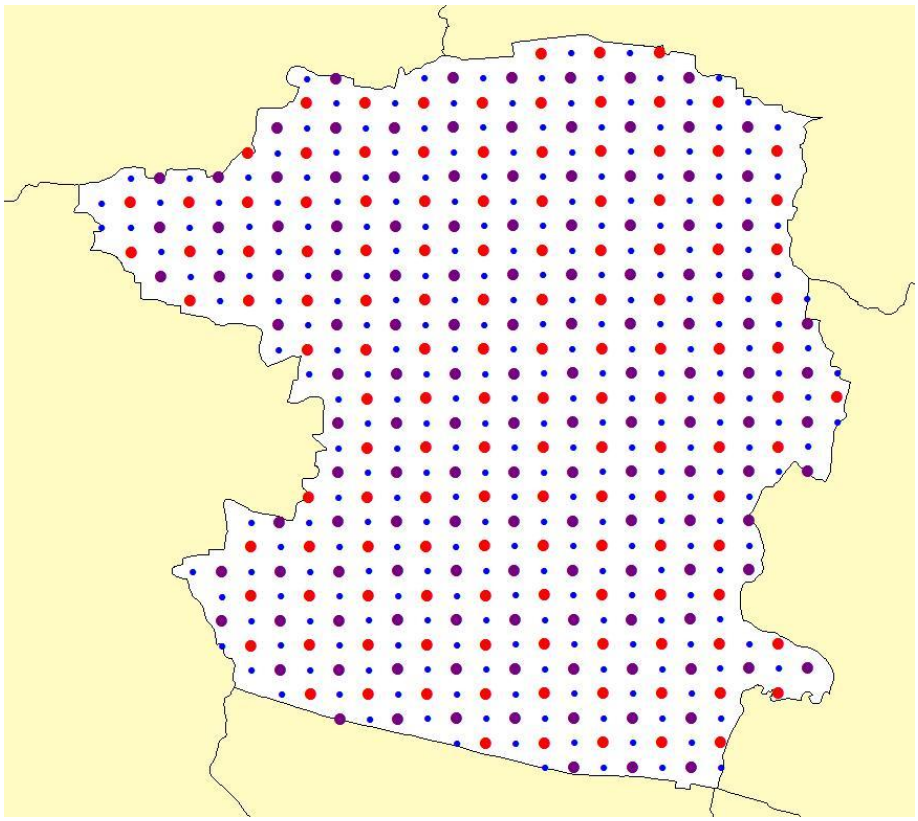


***Figure 2. 9 2 km grid (blue dots); 4 km grid A (red dots); 4 km grid B (purple dot)***

Grids A and B points were interpreted on Google Earth imagery prior to the field survey. The classes of the stratification were defined as follows:

- Arable land
- Non agriculture (urban, artificial, water)
- Permanent crops / poplars
- "Thematic" doubt (doubt between arable and non-arable land)
- "Geometric" doubt i.e. point falling on arable/non arable border

About 20 to 30% of the GE coverage of the Mengcheng County was based on Landsat TM data

(30m) at the time of the interpretation of the 4km grids. No VHR images were available. As a result, from 14 to 22% of the points mainly located on the eastern part of the county were considered as doubtful by the interpreter (Figure 2. 10).

***Figure 2. 10 Example of grid point falling on TM data and considered doubtful***

The 100 points serving as seeds for the segments to be surveyed in the arable stratum were selected as follows: a grid of points located every 4 km was built and interpreted. Some 94 arable points were found on this grid (grid B), a 2nd grid, shifted by 2 km in X and Y with respect to the first one was created and interpreted on Google Earth (GE) prior to the survey (grid A). The six arable points needed to reach the target of 100 was randomly drawn from the set of arable points of this second grid.

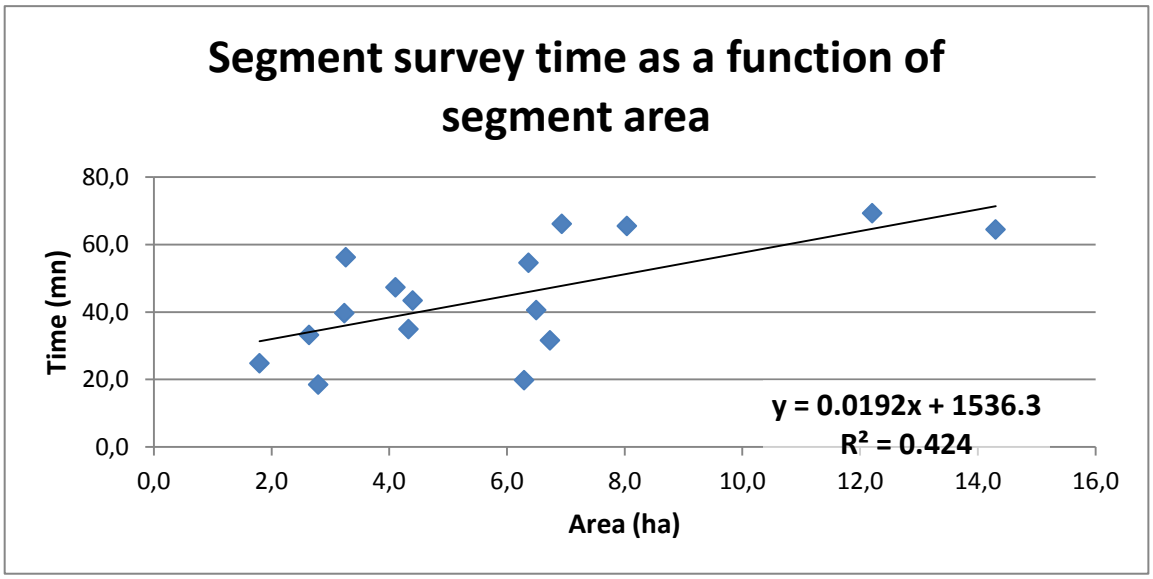
Segments of irregular size were drawn around each of the 100 arable points following the physical boundaries observed on GE imagery. Since it was noticed on the GE VHR imagery that the fields present a structure of narrow strips, the survey technique was adapted and redesigned to take advantage of this structure: starting from a corner, the surveyor had to walk perpendicularly to the strips and mark each start of a new crop as shown on Figure 2. 11 below. The same operation was repeated on the opposite boundary of the segment. In case the crop

plot would not be a rectangle, the surveyor had to walk around the plot perimeter to take points every second. Points were taken using a Trimble GeoXT in stand-alone mode.

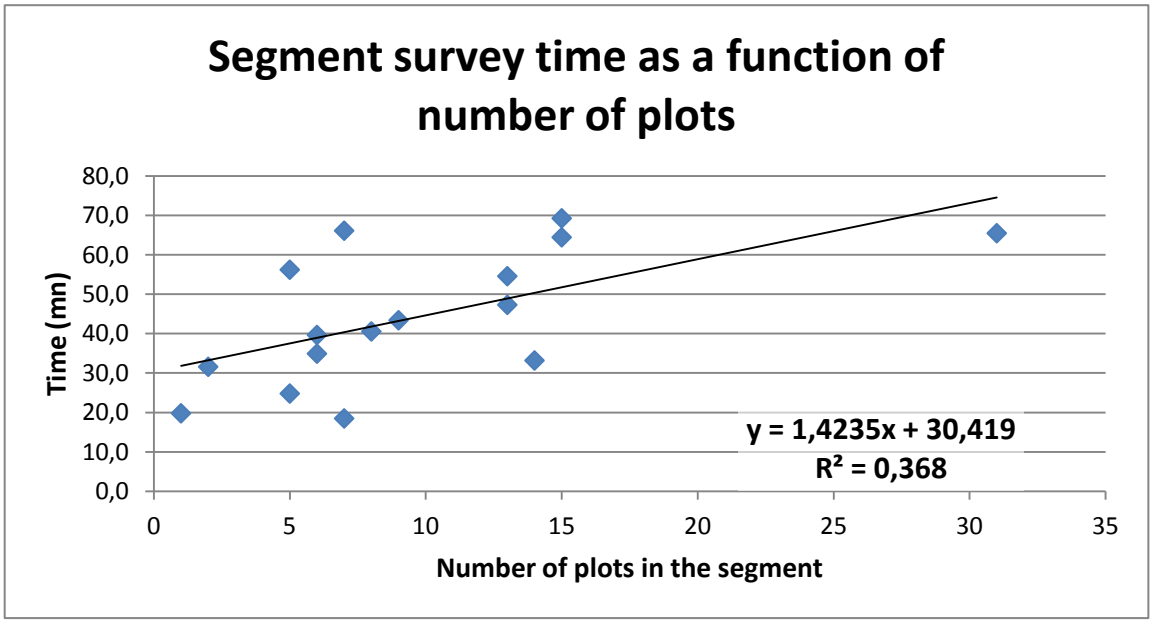

***Figure 2. 11 Methodology followed for surveying the segments***

The method was applied to surveyed 83 segments. The navigation to the segments was made using a GPS connected to a laptop on which a recent HR image was displayed. For one segment (B120) close to the Mengcheng city, the land cover had changed from arable land on the 2004 GE image to built-up area (Figure 2.25). The survey was executed in two close periods of time. The first 16 segments were survey with 3,5 days and the rest of 67 segments were carried out with a second period of 15 days. Without considering the time to reach the segment, the survey of a segment took from 18.5 mn for a 2.8 ha segment with 7 plots to nearly 70 mn for a 12.2 ha segment with 15 plots. Figure 2.12a below shows the relation between the segment total area and the time to survey the segment while Figure 2.12b shows the relation between the survey time and the number of different plots in the segment. On average 45 mn were needed per segment, with an average segment size of 5.9 ha.

Figure 2. 13 below shows the distribution of the 16 + 67 segments surveyed. A stripe with no segment can be observed to the east; this is due to the fact that arable points could not be identified with confidence on the TM data available on GE for the 1st stratification. However since the landscape is homogeneous on the whole county, this should not introduce any bias.




a




b

***Figure 2. 12 a & b: Segment survey time as a function of (a) segment area and (b) number of plots in the segment***

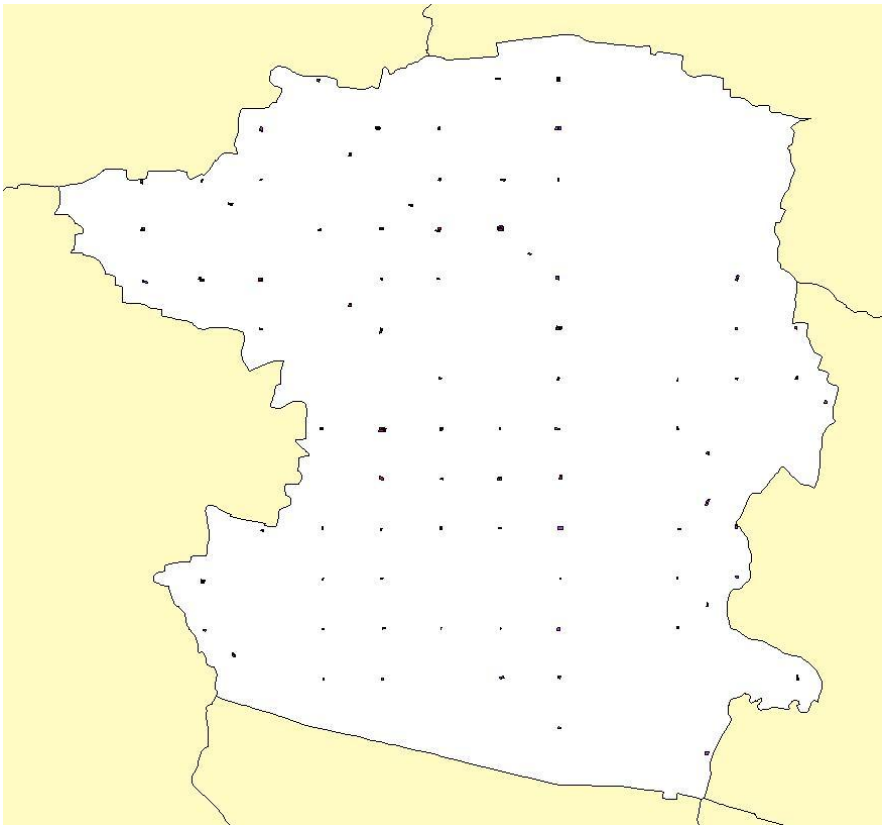


*Figure 2. 13 Distribution of the 83 surveyed segments*

#### 2.2.1.2 The Ground sampling units for validation

According to the remote sensing images and the offical statistical data, it could be found that Mengcheng was a large agricultural county mainly planting of winter wheat and maize and soybean. The area of winter wheat accounted for 88% of the arable land in winter. The total area of maize and soybean accounted for 83% of the arable land in summer. In this situation, the gound sampling units should be more evenly distributed within the county. At the same time, the each sampling unit must fall within the arable land, and was easy to reach. So we adopt the grid-based radom sampling method to design the units. There were there main steps.

Step one: to determine the remote sensing monitoring classification system of Mengcheng county based on the remote sensing images.

- Arable land: land to grow crops, including vegetated land and recreational land;
- Roads: including expressways, national highways and provincial roads, county roads;
- Settlements: urban land use, rural settlements;
- Water body: rivers, ponds and reservoirs;

- Woodland: does not contain the nursery or fast-growing trees planted in arable land.

Step two: to design the sample frame ( See Figure 2.14).

- Mengcheng was divided into 5′×5′ grids. All the grids in the county boundary are included;
- There were 40 squares in Mengcheng county in total.

Step three: to design the position and size of the ground sampling units.

- All ground sampling units should be in the grids, and each unit corresponds to one grid;
- There were 30 ground sampling units in total.
- The minimum distance between the two units should be greater than 10km.
- Taking into account the time of field survey, and according to past experience, the average size of sample units was set to 500m × 500m;
- All units use the physical boundary of the fields.

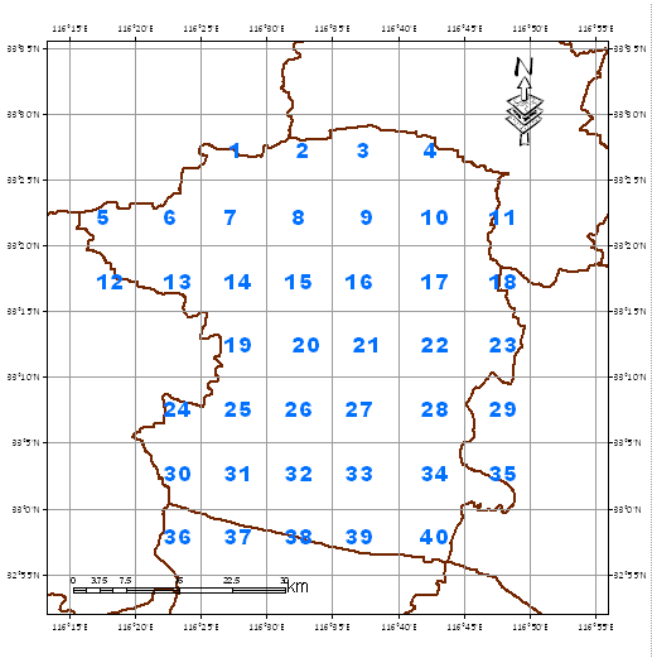



***Figure 2. 14 The sample frame of Mengcheng county***

The design of field sampling frame was basically completed through above process. These units would be used as interpretation signs and validation data.

## 2.2.2 Guoyang County

For Guoyang county, an Area Frame Sampling (AFS) scheme based on systematic sampling with

circle boundaries was devised. From this AFS, a total of 193 sampling units were designed according to the rule of sampling at equal interval. The average area of each unit was 4.62 hectare, and the field survey was conducted from March 2012 to August 2012 respectively. The Trimble GeoXT2000 Differential GPS was used to investigate the areas and boundary of each crop within the units. The specific processes are described as follows:

Step one: to determine the remote sensing monitoring classification system of Guoyang county. It was as same as the system of Mengcheng county.

Step two: to design the AFS based on systematic sampling with circle boundaries.

- Guoyang county was divided into 0.01°×0.01° ( 36”×36” ) grids. All the grids in the county boundary are included;
- In order to provide convenience for field investigation and positioning, the cross point coordinate of each grid must be the integer multiples of 0.01°;
- By taking the cross point of each grid as the centre, circles with radius of 120m and area of 4.52ha were established, and there were 2074 circles in Guoyang county in total. (See Figure 2.15)

Step three: Pre-identification of sampling units based on GoogleEarth ( See Figure 2.16).

- Based on the established classification system and by taking GoogleEarth as the base map, visual interpretation method was used to draw the land use map for each selected circle, and to identify the land use type of the covered areas of each circle.
- When the areas of arable land of a circle exceeded 50%, the circle was defined as cropland, otherwise it was defined as non-cropland. Among 2,074 circles, 1732 circles were identified as cropland, accounting for 83.5%; 342 circles were identified as non-cropland, accounting for 16.5%.

Step four: Identification of cropland sampling units

- Equal interval sampling at proportion of 10 percent was conducted among 1732 circles which were defined as cropland, and the first sampling point was selected by random sampling;
- A total of 193 circles were sampled and the interval between two circles was 0.03°. Each circle was a ground sampling unit. ( See Figure 2.17).

Step five: to make landcover map of the sampling unit ( See Figure 2.18) .

- The projection of the landuse map extracted from the GoogleEarth was converted into latitude and longitude coordinates and it was saved in a shapefile format, and then imported into GPS ( Trimble GeoXT).

The design of field sampling frame was basically completed through above process, and the crop area sampling survey program based on ground survey were carried out based on this field sampling frame. These units would be used as interpretation signs and validation data. At the same time, these samples will be used for the crop area spatial extrapolation.

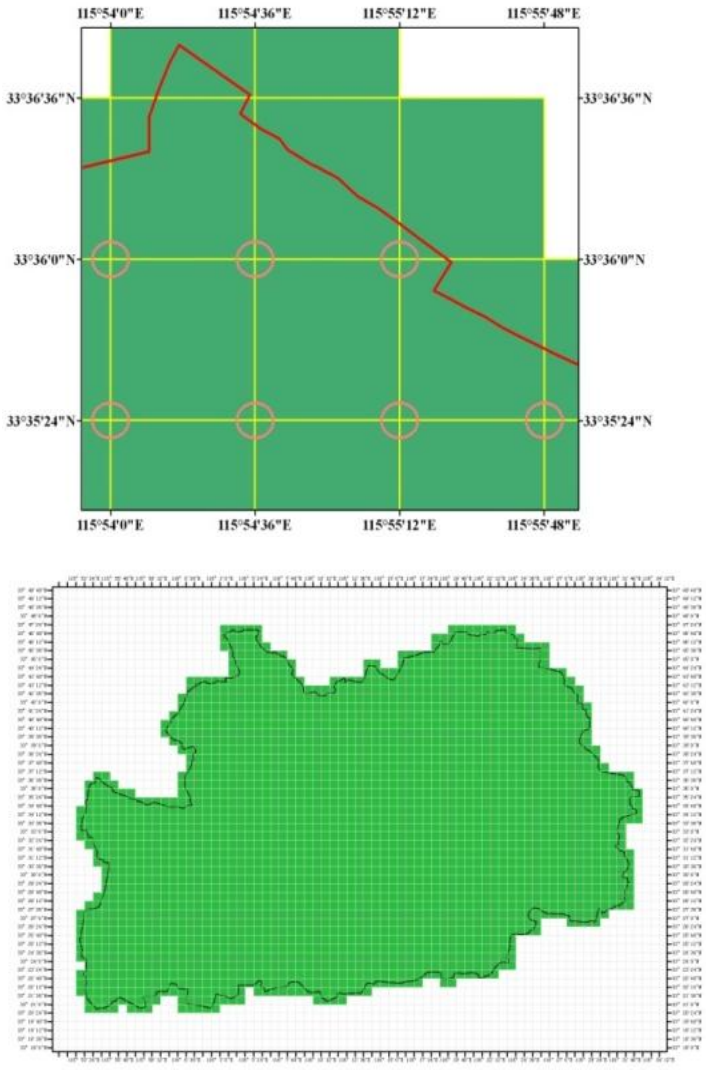



***Figure 2. 15 The second step for ground sampling units***

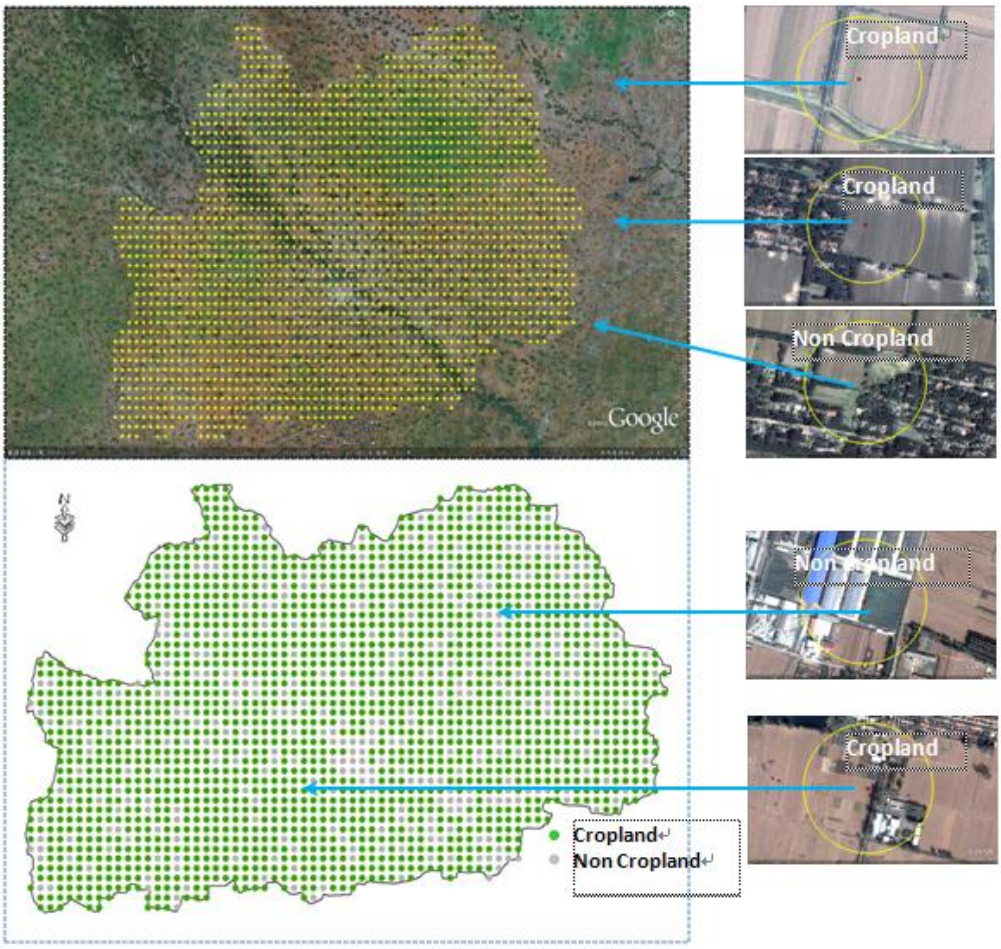



*Figure 2.16 The third step for ground sampling units*

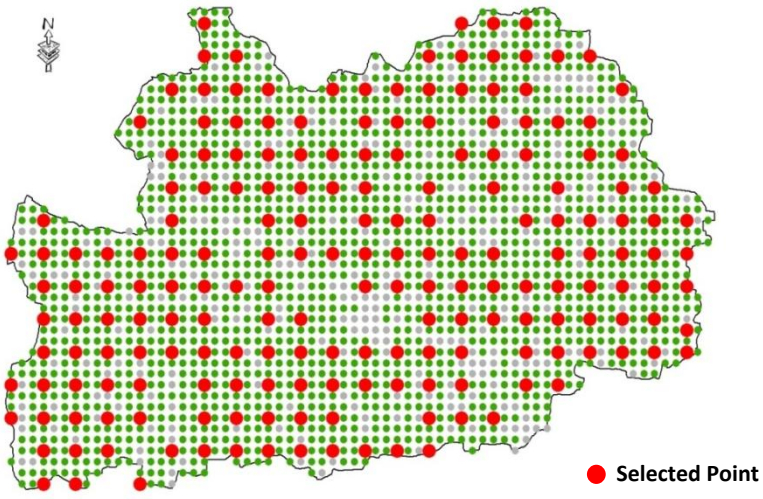



*Figure 2.17 The forth step for ground sampling units*

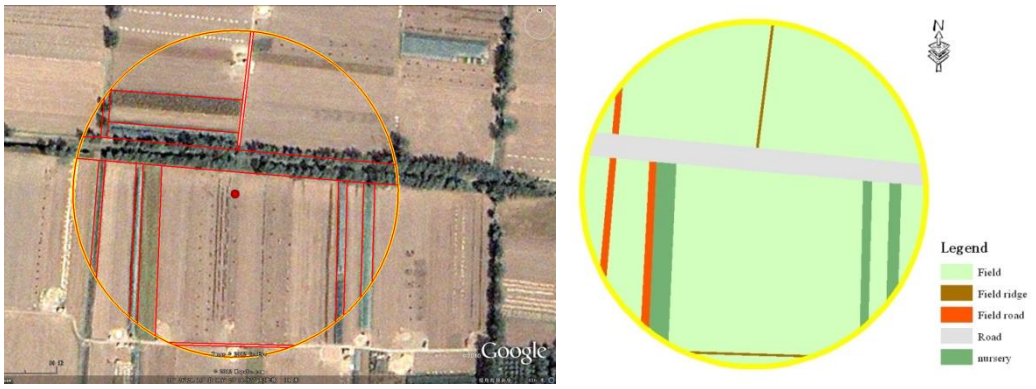



***Figure 2.18 The fifth step for ground sampling units***

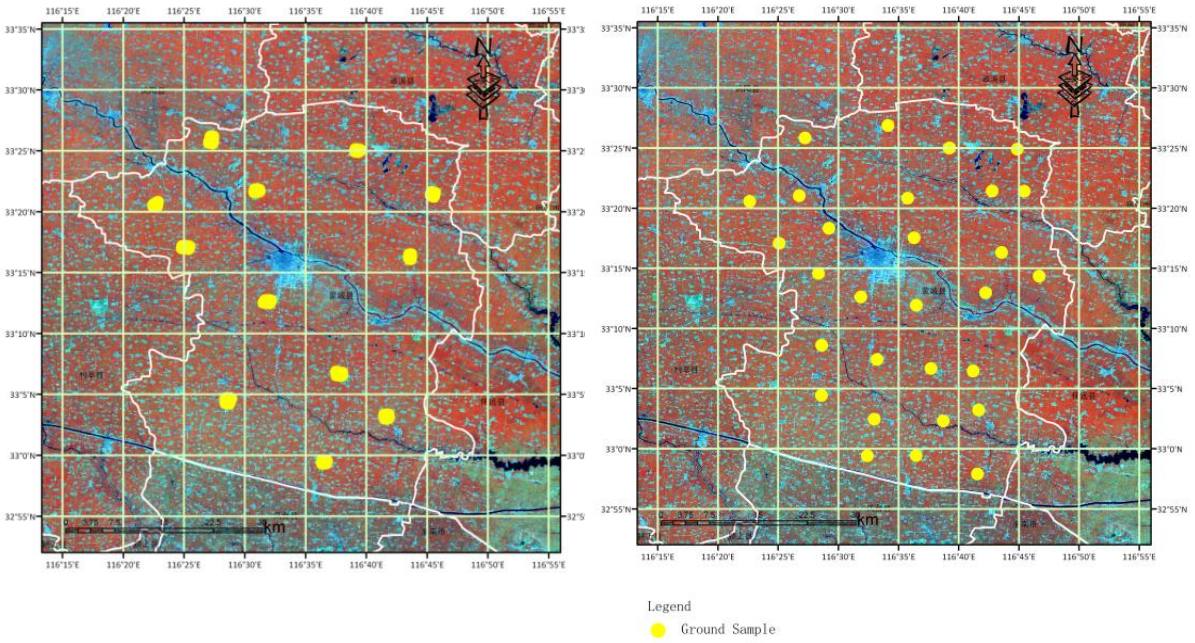
## 2.3 Survey of Ground Sampling Units

### 2.3.1 Mengcheng County

Three times of field survey had been carried out based on the field sampling frame in Mengcheng County.

The first time was from June 8 to 12 in 2011. According to the old program design, only 12 ground sampling units of winter wheat had been measured through differential GPS, each unit measured 500m×500m on average ( Figure 2.19a ). Every unit had physical boundary. For second time, we changed the program design and adjusted the number of gound sampling units, 18 units were added based on the original ( Figure 2.19b ). The survey time was from July 18 to 25 in 2011 for collecting maize ground information. All units had physical boundary. The third time was from November 15 to 23 for collecting wheat winter ground information.

The results were saved in the “Field_MC_Wheat_201106.shp” and “Field_MC_Maize_201107.shp” and “Field_MC_Wheat_201111.shp”.




(a) (b)

***Figure 2.19 The distribution of the ground sampling units***

## 2.3.2 Guoyang County

Three times of field survey was conducted in Guoyang county. The first time was from April 4 to 21 in 2012. The main crop was winter wheat. The second time was from July 3 to 21. The main crops were soybean and maize. Four staff participated in the field measurement. They spent 18 days to complete measurement of 193 sampling units.

When the field map had no change, then the crop type of each land block was directly marked on the map; when the boundary was changed, the GPS was used to record the changed boundary of the land block, and the crop type of each land block was marked on the map.

Data preparation and measurement process is shown in Figure 2.20 to 2.21. The results were saved in the “Field_GY_Wheat_201204.shp” and “Field_GY_Maize_201207.shp”.

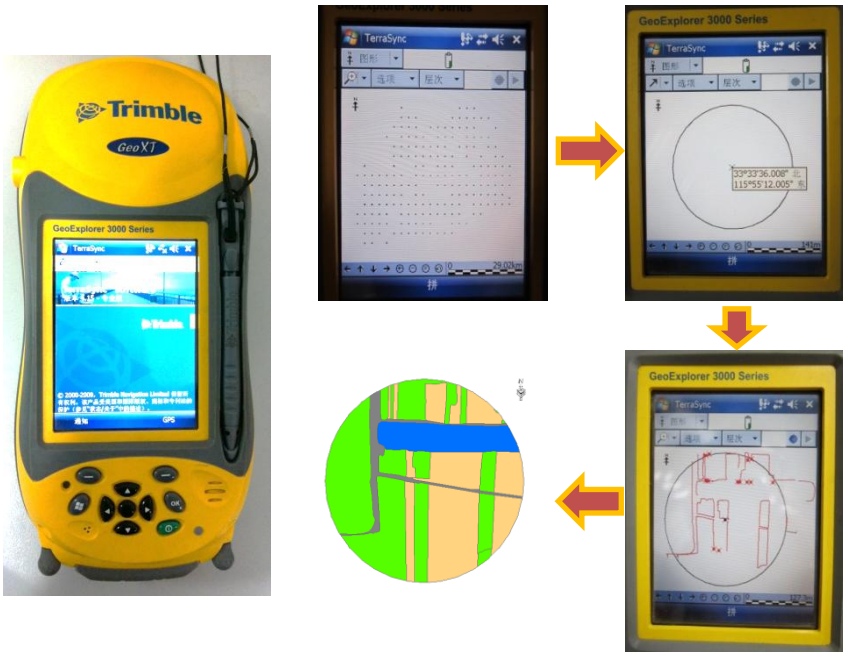



*Figure 2.20 Field sampling process*

*Figure 2.21 Field sampling photos*

# 2.4 Segment sampling database

## 2.4.1 Mengcheng County

### 2.4.1.1 The Ground sampling units for the spatial extrapolation

Table 2.11 below shows the crop area statistics of the 16 segments surveyed in the first period while Table 2.12 provides the same statistics for the segments surveyed in the second period.

Table 2.13 provides the synthesis of the whole sample set. On average **maize and soybean** cover nearly **77% and 20% of the arable land** respectively.

It can be noticed that the segments surveyed in the first period, which were located around Mengcheng city, were larger (nearly 6 ha on average vs 3.3 ha), had a higher percentage of maize (nearly 90% vs 74%) and a lower percentage of soybean (10% vs 22%) than the ones surveyed in the second period. The smaller segment size in the second sample sub-set is mainly due to the choice of the surveyors to take as segment limits the first parcel boundaries found in the field whereas originally the surveyors had tried to follow the segments boundaries identified on the GE imagery. This has no impact on the estimations.

***Table 2.11 Statistics about the 16 segments surveyed in August 2011, Mengcheng***

| | Maize | Soybean | Other crops | Non agriculture |
|---|---|---|---|---|
| **Average (%)** | **89.5%** | **9.9%** | 0.5% | 0.1% |
| **Std dev (%)** | 2.3% | 2.3% | 0.3% | 0.3% |
| **Total Area (ha)** | 83.99 | 9.50 | 0.31 | 0.11 |
| **Average, min and max segment Size** | **5.87 ha / 1.8 ha - 14.3 ha** | | | |

***Table 2.12 Statistics about the 67 segments surveyed in September 2011, Mengcheng***

| | Maize | Soybean | Other crops | Non agriculture |
|---|---|---|---|---|
| **Average (%)** | **73.8%** | **22.1%** | 3.6% | 0.5% |
| **Std dev (%)** | 3.2% | 3.0% | 1.6% | 0.2% |
| **Total Area (ha)** | 158.09 | 51.52 | 9.22 | 0.72 |
| **Average, min and max segment Size** | **3.28 ha / 0.6 ha – 8.8 ha** | | | |

***Table 2.13 Statistics about all the segments (83) , Mengcheng***

| | Maize | Soybean | Other crops | Non agriculture |
|---|---|---|---|---|
| **Average (%)** | **76.8%** | **19.8%** | 3.0% | 0.4% |
| **Std dev (%)** | **2.7%** | **2.5%** | 1.3% | 0.2% |
| **Total Area (ha)** | 242.08 | 61.02 | 9.53 | 0.83 |
| **Average segment Size** | **3.78 ha** | | | |

## Segment sample stratification

The results from the various stratifications are presented in

Table 2.14 below:

- Preliminary stratification made on grids A and B (4 km grids) and used for selecting the 100 arable segments to be surveyed; interpretation based on GE imagery.
- Second stratification of the same 2 grids focussing on doubtful points (thematic doubt) and based either on the new GE VHR imagery on the one hand and on Spot 2.5m 2011 imagery acquired after the field survey on the other hand;
- 3rd stratification based on spot 2.5m 2011 imagery and a 2 km grid (532 points) comprising the first two 4km grids; the percentage of arable land in the county was derived from this stratification. For comparison purposes, this same grid was also interpreted on the new GE imagery.

No point falling on a permanent crop (or small wood) was found; as areas with trees correspond to villages, points falling on such areas were affected to the non agriculture stratum. Points falling on the centre of tree hedges were assigned to the non agriculture stratum as points falling on a roads, paths, irrigation canals (Figure 2.22) whereas points falling at the border of hedges were affected to the "geometric doubt" stratum (Figure 2.23).

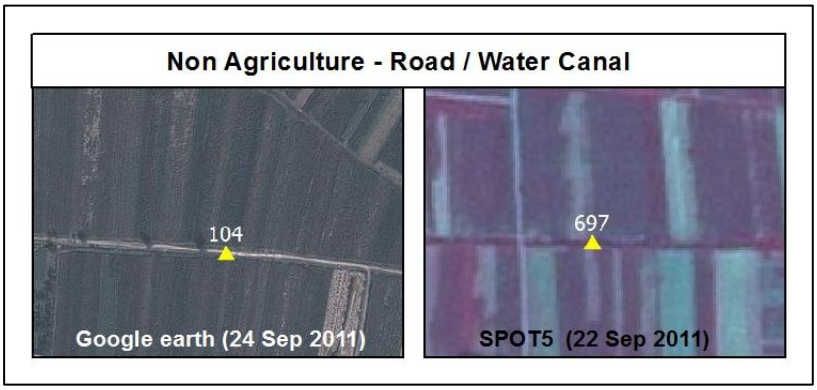



***Figure 2.22 Points fall on a road (104) and on a water canal (697)***

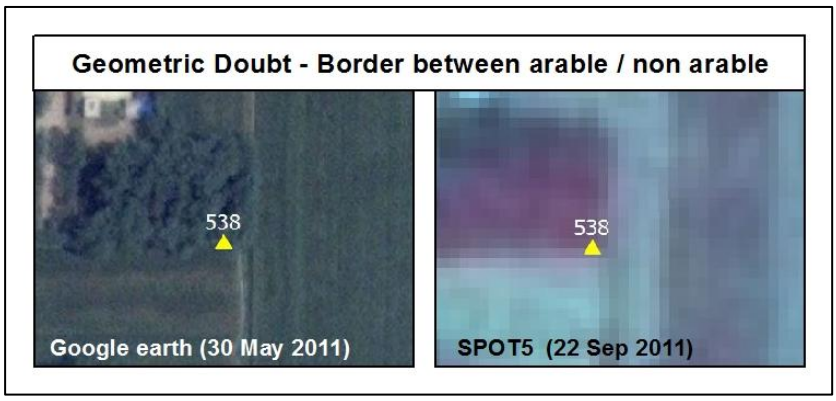



*Figure 2.23 Point falls on the border between woodland and cropland (geometric doubt)*

*Table 2.14 Stratification results, Mengcheng*

(a) Preliminary stratification based on Google Earth imagery (2004) for grids A and B (4 km grids)

| Stratum | Grid A | Grid B | Grid A % | Grid B % |
|---|---|---|---|---|
| **Arable** | 84 | 86 | **63.6%** | **64.7%** |
| **Non agriculture** | 17 | 24 | **12.9%** | **18.0%** |
| **Permanent crop / trees** | 1 | 4 | 0.8% | 3.0% |
| **Not sure arable or not** | 12 | 10 | 9.1% | 7.5% |
| **Border arable / non arable** | 18 | 9 | 13.6% | 6.8% |
| **Total** | **132** | **133** | **100%** | **100%** |

(b) Revised stratification based on new Google Earth imagery (V2, 2011) and SPOT 2011 (grids A and B)

| Stratum | Grid A GE V2 | Grid A SPOT | Grid B GE V2 | Grid B SPOT | Grid A GE(%) | Grid A Spot (%) | Grid B GE (%) | Grid B Spot (%) |
|---|---|---|---|---|---|---|---|---|
| **Arable** | 94 | 105 | 93 | 98 | **71.2%** | **79.5%** | **69.9%** | **73.7%** |
| **Non agriculture** | 18 | 22 | 25 | 26 | **13.6%** | **16.7%** | **18.8%** | **19.5%** |
| **Permanent crop / trees** | 1 | 0 | 4 | 0 | 0.8% | 0% | 3.0% | 0% |
| **Not sure arable or not** | 1 | 0 | 2 | 3 | 0.8% | 0% | 1.5% | 2.3% |
| **Border arable / non arable** | 18 | 5 | 9 | 6 | 13.6% | 3.8% | 6.8% | 4.5% |
| **Total** | **132** | **132** | **133** | **133** | **100%** | **100%** | **100%** | **100%** |

(c) stratification based on Spot 2.5m image of 22/09/2011 and GE and a 2km grid (532 points). Doubtful points were reallocated to the arable stratum using 3 hypotheses: 50%, 0%, 100% of the doubtful points are arable. The 6 points falling outside the Spot image were reallocated proportionally to the importance of the arable, non-agriculture and permanent crop strata (i.e. 76% of these 6 points were considered arable)

| | | **Spot 5 (2011)** | | | |
|---|---|---|---|---|---|
| | | | Reallocation | | |
| **Stratum** | # points | % | 50% | 0% | 100% |
| **Arable** | 379 | **71.2** | **73.1** | 72.1 | 74.1 |
| **Non agriculture** | 136 | **25.6** | **26.9** | 27.9 | 25.9 |
| **Permanent crop / trees** | 0 | 0.0 | | | |
| **Not sure arable or not** | 1 | 0.2 | | | |
| **Border arable / non arable** | 10 | 1.9 | | | |
| **Outside image** | 6 | 1.1 | | | |
| **Total** | 532 | 100 | 100 | 100 | 100 |

| | | **Google Earth (2004-2011)** | | | |
|---|---|---|---|---|---|
| | | | Reallocation | | |
| **Stratum** | # points | % | 50% | 0% | 100% |
| **Arable** | 397 | **74.6** | **76.3** | 74.6 | 78.0 |
| **Non agriculture** | 117 | **22.0** | **23.7** | 25.4 | 22.0 |
| **Permanent crop / trees** | 0 | 0.0 | | | |
| **Not sure arable or not** | 0 | 0.0 | | | |
| **Border arable / non arable** | 18 | 3.4 | | | |
| **Total** | 532 | 100 | 100 | 100 | 100 |

(d) Agreement between the Spot 2.5m and the GE stratifications

| | | GE imagery | | | | | |
|---|---|---|---|---|---|---|---|
| | | No satellite data | Arable Land | Non agriculture | Thematic doubt | Geometric doubt | Total |
| Spot5 (22/9/2011) | No satellite data | **0** | 6 | 0 | 0 | 0 | 6 |
| | Arable Land | 0 | **366** | 9 | 0 | 4 | 379 |
| | Non agriculture | 0 | 20 | **106** | 0 | 10 | 136 |
| | Thematic doubt | 0 | 1 | 0 | **0** | 0 | 1 |
| | Geometric doubt | 0 | 4 | 2 | 0 | **4** | 10 |
| | Total | 0 | 397 | 117 | 0 | 18 | 532 |

Assuming that the county area is of 2148.8 km2, the arable land stratum is of 157,075 ha (73.1% of 2148.8 km2). The maximum error due to the reallocation of the doubtful points is of 2,222 ha i.e. 1.4% of the estimated area.

In total 50 points, i.e. 9% of the points of the 2km grid, were classified differently using GE and Spot5 images (

Table ***2.14***d). Most of these changes are due to differences in the registration of the respective images ( Figure 2.24 ). However for seven of these 50 points, a real land cover change occurred between the date of the GE images (2004-2011) and summer 2011 (see Figure 2.25) Six of those seven points changed from arable to non-arable while one had the opposite change. Figure 2.25 shows one arable segment close to Mengcheng city fully converted into a large road, another point falling on a village area in 2004 appearing to be on a fully arable area in 2011, and finally an arable land in 2004 converted to woodland in 2011

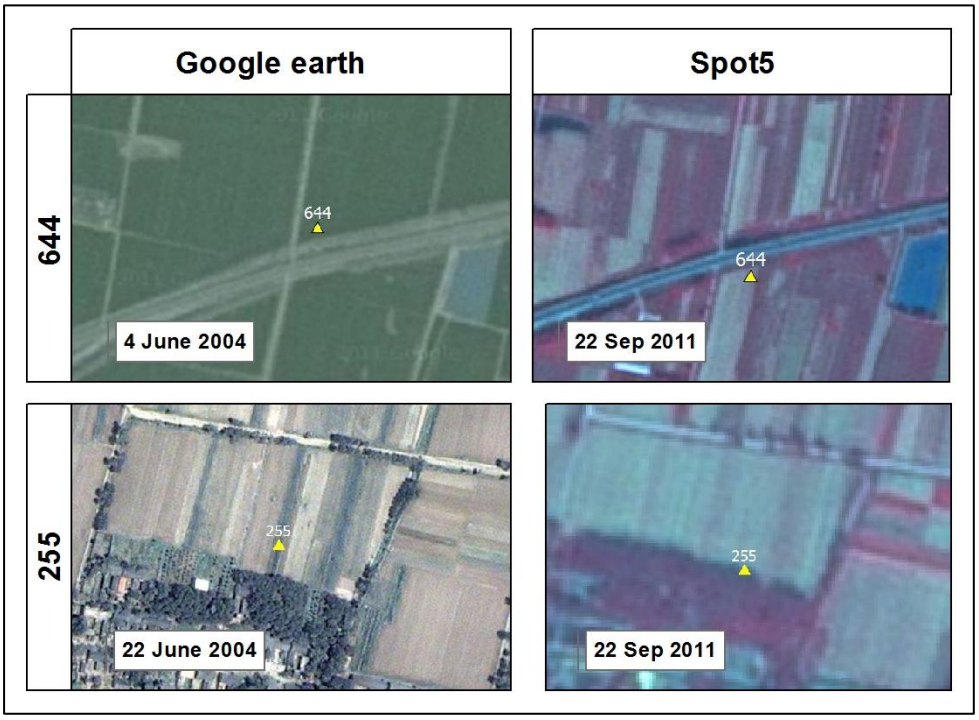



***Figure 2.24 Differences in the registration of SPOT5 and GE images***

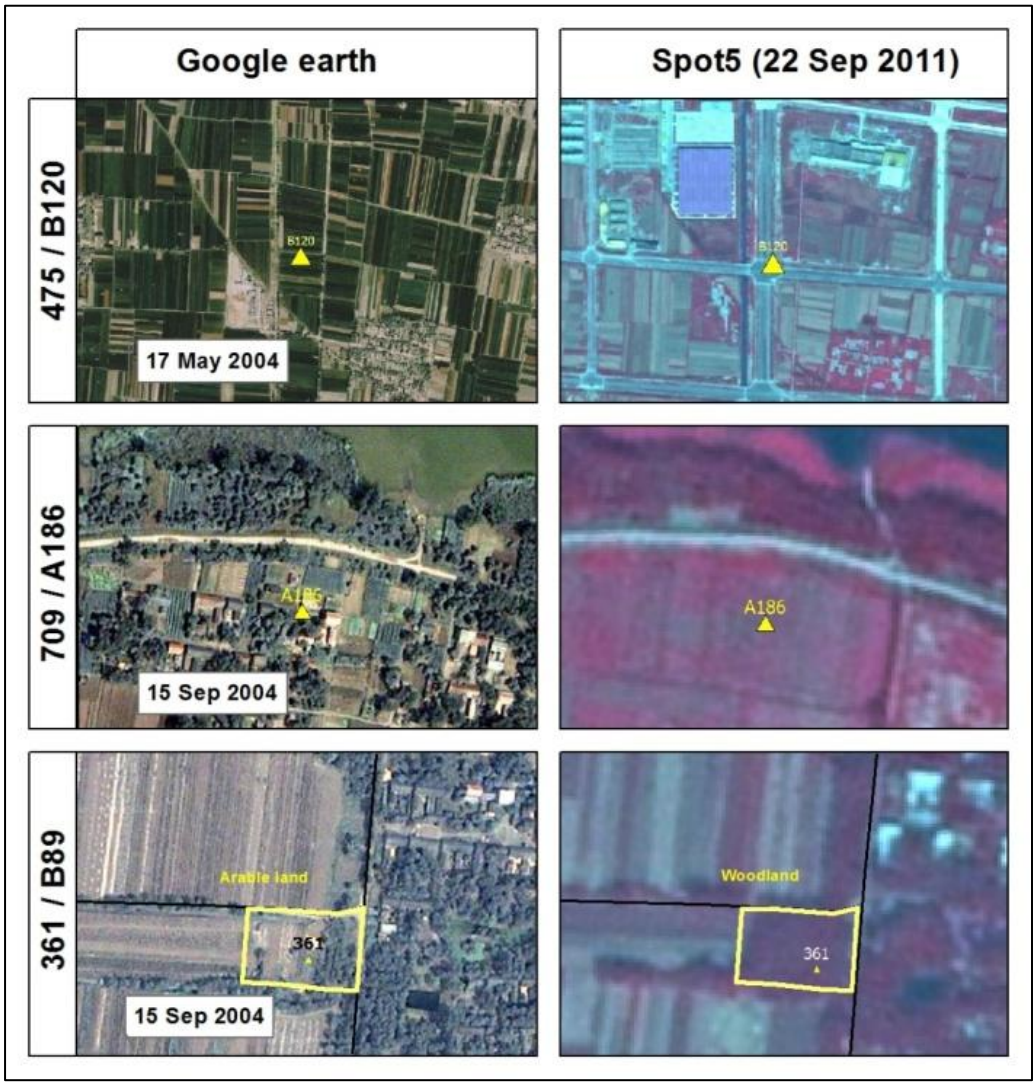



***Figure 2.25 Changes in land cover between GE 2004 imagery and Spot 2011 imagery (top: conversion of arable land into built up / road area; middle: conversion of a village area into arable land, bottom: conversion of arable land to Woodland).***

### 2.4.1.2 The Ground sampling units for validation

The database contains vector files that were produced in the design of sampling units, Raw GPS data, GPS routes, photoes, sketches, etc. , that were acquired in the field investigation process, as well as the vector files of the field survey results.

Figure 2.26 shows the survey results of some sampling units.

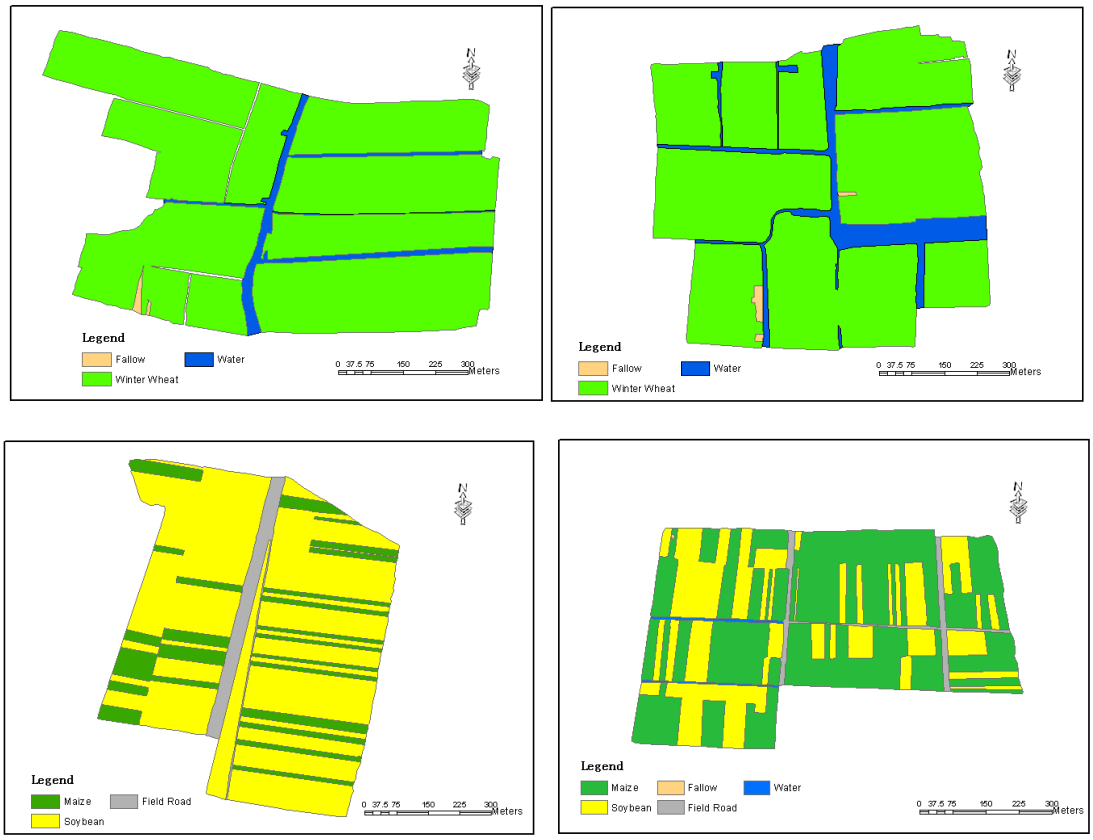



***Figure 2.26 The landcover map of Mengcheng ground sampling units***

Table.2.15 shows the statistics of winter wheat area from 2011 to 2012. Table.2.16 shows the statistics of maize area in 2012.

***Table 2.15 The statistics of Mengcheng winter wheat area from 2011 to 2012***

| Code | Position | Total Area ($m^2$) | Winter Wheat Area ($m^2$) | | Variation ($m^2$) | Reason |
|---|---|---|---|---|---|---|
| | | | 2010-2011 | 2011-2012 | | |
| dm340012011 | Mengcheng | 292547.203 | 286622.75 | 286729.75 | 107 | —— |
| dm340022011 | Xuzhai | 258043.266 | 205787.078 | 245929.5 | 40142.422 | fallow→winter wheat |
| dm340032011 | Qianmajia | 271801.016 | 222037.391 | 216337 | -5700.391 | winter wheat→fallow |
| dm340042011 | Xiaochenzhuang | 278382.5 | 266042.547 | 266546.219 | 503.672 | —— |
| dm340052011 | Xiaojian | 491820.375 | 472031.5 | 456682.516 | -15348.984 | winter wheat→fallow |
| dm340062011 | Mengcheng | 429826.367 | 391710.859 | 392450.359 | 739.5 | —— |

| | | | | | | |
|---|---|---|---|---|---|---|
| dm340072011 | Xiwang | 319884.555 | 299642.656 | 296417.18 | -3225.476 | fallow→winter wheat |
| dm340082011 | Caiyoufang | 408184.531 | 380870.844 | 381200.188 | 329.344 | —— |
| dm340092011 | Xiezhuang | 426372.391 | 401127.031 | 396623.406 | -4503.625 | winter wheat→fallow |
| dm340102011 | Licang | 406786.438 | 404193.094 | 360351.563 | -43841.531 | winter wheat→fallow |
| dm340112011 | Guozhuang | 312162.953 | 293881.219 | 295676.203 | 1794.984 | fallow→winter wheat |
| dm340122011 | Mengcheng | 579180.891 | 548962.156 | 507870.641 | -41091.515 | winter wheat→fallow |
| dm340132011 | Mengcheng | 273179.2282 | | 260632.3277 | | |
| dm340142011 | Mengcheng | 286470.3538 | | 271423.3613 | | |
| dm340152011 | Mengcheng | 340417.1728 | | 259441.7532 | | |
| dm340162011 | Youzhuang | 301985.3323 | | 290289.3101 | | |
| dm340172011 | Limiao | 269678.8655 | | 255320.0052 | | |
| dm340182011 | Zhangzhuang | 213970.5007 | | 203338.5468 | | |
| dm340192011 | Maweiba | 348006.565 | | 328794.2074 | | |
| dm340202011 | Liqiao, | 228631.5314 | | 189178.3574 | | |
| dm340212011 | Mengcheng | 176783.3058 | | 137110.0935 | | |
| dm340222011 | Mengcheng | 178839.3202 | | 168795.4408 | | |
| dm340232011 | Mengcheng | 117574.0675 | | 108979.5205 | | |
| dm340242011 | Mengcheng | 212497.8371 | | 202923.8692 | | |
| dm340252011 | Mengcheng | 260029.5092 | | 240504.4927 | | |
| dm340262011 | Mengcheng | 223537.0746 | | 205992.0852 | | |
| dm340272011 | Mengcheng | 333711.9745 | | 322752.7547 | | |
| dm340282011 | Mengcheng | 261934.2866 | | 240979.709 | | |
| dm340292011 | Yuefang | 160364.8291 | | 155829.7661 | | |
| dm340302011 | Hetong | 269505.453 | | 262222.625 | | |

*Table 2.16 The statistics of Mengcheng maize area from in 2012*

| Code | Position | Total Area ($m^2$) | Maize Area (2012) ($m^2$) |
|---|---|---|---|
| YM340012011 | Mengcheng | 292547.2 | 286622.8 |
| YM340022011 | Xuzhai | 258043.266 | 231348.766 |
| YM340032011 | Qianmajia | 271805.6 | 162509.8 |
| YM340042011 | Xiaochenzhuang | 278382.5 | 170769.188 |
| YM340052011 | Mengcheng | 491820.4 | 54246.5 |
| YM340062011 | Mengcheng | 429826.367 | 388547.094 |
| YM340072011 | Guiying | 319884.6 | 245605.6 |
| YM340082011 | Caiyoufang | 395867.984 | 379564.141 |
| YM340092011 | Xiezhuang | 426362.8 | 394496.6 |
| YM340102011 | Zhenqiaozhuang | 406790.391 | 315073.141 |
| YM340112011 | Guozhuang | 312163.0 | 273848.9 |
| YM340122011 | Mengcheng | 579172.234 | 502318.484 |
| YM340132011 | Mengcheng | 273179.2 | 70627.4 |
| YM340142011 | Mengcheng | 286470.3538 | 248244.8824 |
| YM340152011 | Mengcheng | 340417.2 | 244088.1 |
| YM340162011 | Youzhuang | 301985.3323 | 255557.5105 |
| YM340172011 | Limiao | 269678.9 | 254765.9 |
| YM340182011 | Zhangzhuang | 213970.5007 | 196866.2548 |
| YM340192011 | Maweiba | 348006.6 | 63216.0 |
| YM340202011 | Liqiao | 228631.5314 | 176721.4995 |
| YM340212011 | Mengcheng | 176783.3 | 133607.2 |
| YM340222011 | Mengcheng | 178839.3202 | 162597.7499 |
| YM340232011 | Mengcheng | 117574.1 | 100289.7 |
| YM340242011 | Mengcheng | 212497.8371 | 183044.4988 |
| YM340252011 | Mengcheng | 260029.5 | 226817.2 |
| YM340262011 | Mengcheng | 223537.0745 | 203159.9537 |
| YM340272011 | Mengcheng | 333712.0 | 296687.5 |

| Code | Position | Total Area ($m^2$) | Maize Area (2012) ($m^2$) |
|---|---|---|---|
| YM340282011 | Mengcheng | 261934.2866 | 248557.1649 |
| YM340292011 | Mengcheng | 160391.4 | 97598.9 |
| YM340302011 | Mengcheng | 252941.787 | 178611.3871 |

## 2.4.2 Guoyang County

Figure 2.27 shows the survey results of some sampling units.

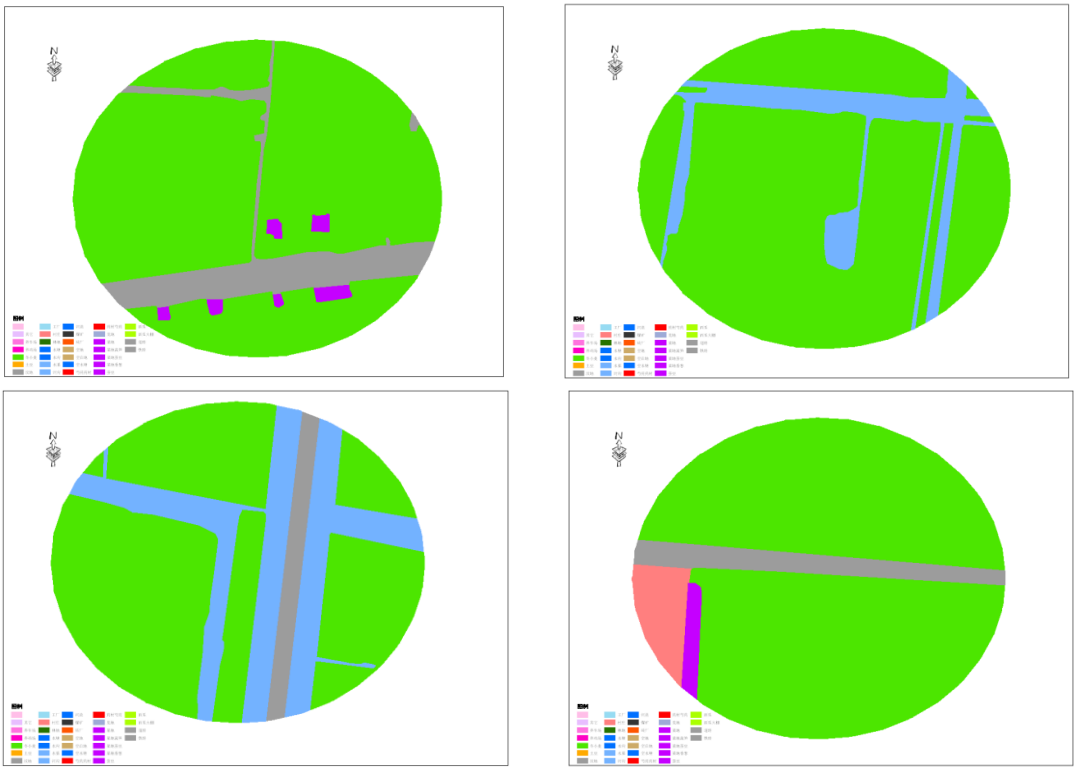


***Figure 2.27 The landcover map of Guoyang ground sampling units***

Table.2.17 shows the statistics of winter wheat area in 2012. Table.2.18 shows the statistics of maize and soybean area in 2012.

***Table 2.17 The statistics of Guoyang winter wheat areain 2012***

Unit: $m^2$

| ID | Winter Wheat | Other | Total |
|---|---|---|---|
| 1 | 41637.682 | 2199.620 | 43837.3 |
| 2 | 40516.722 | 3287.680 | 43804.4 |
| 3 | 43842.002 | 0.000 | 43842.0 |
| 4 | 38183.150 | 5642.402 | 43825.6 |
| 5 | 34051.812 | 9764.340 | 43816.2 |
| 6 | 37854.147 | 5959.655 | 43813.8 |
| 7 | 36857.738 | 6932.564 | 43790.3 |
| 8 | 39459.212 | 4387.490 | 43846.7 |
| 9 | 31908.593 | 11881.709 | 43790.3 |
| 10 | 41325.129 | 2507.473 | 43832.6 |
| 11 | 39167.809 | 4669.493 | 43837.3 |
| 12 | 15507.792 | 28298.959 | 43806.8 |
| 13 | 41755.183 | 2058.619 | 43813.8 |
| 14 | 41296.929 | 2538.023 | 43835.0 |
| 15 | 42967.794 | 843.658 | 43811.5 |
| 16 | 40627.173 | 3184.279 | 43811.5 |
| 17 | 27264.950 | 16551.202 | 43816.2 |
| 18 | 40902.125 | 2899.927 | 43802.1 |
| 19 | 42048.936 | 1739.016 | 43788.0 |
| 20 | 38472.203 | 5346.299 | 43818.5 |
| 21 | 39532.062 | 4298.189 | 43830.3 |
| 22 | 40291.119 | 3525.032 | 43816.2 |
| 23 | 35755.578 | 8062.924 | 43818.5 |
| 24 | 29201.368 | 14617.134 | 43818.5 |
| 25 | 28872.365 | 14927.337 | 43799.7 |
| 26 | 35269.123 | 8544.678 | 43813.8 |
| 27 | 40307.570 | 3480.382 | 43788.0 |
| 28 | 37567.444 | 6260.457 | 43827.9 |
| 29 | 39329.961 | 4504.991 | 43835.0 |
| 30 | 41395.630 | 2446.372 | 43842.0 |
| 31 | 40293.469 | 3541.482 | 43835.0 |
| 32 | 26212.140 | 17578.161 | 43790.3 |
| 33 | 40631.873 | 3198.379 | 43830.3 |
| 34 | 43238.046 | 571.055 | 43809.1 |
| 35 | 39614.313 | 4180.688 | 43795.0 |
| 36 | 41618.882 | 2206.670 | 43825.6 |
| 37 | 35426.575 | 8363.727 | 43790.3 |
| 38 | 19122.125 | 24729.277 | 43851.4 |
| 39 | 40476.771 | 3362.881 | 43839.7 |
| 40 | 39419.261 | 4415.690 | 43835.0 |
| 41 | 40939.725 | 2899.927 | 43839.7 |
| 42 | 42937.244 | 850.708 | 43788.0 |
| 43 | 42972.494 | 862.458 | 43835.0 |
| 44 | 32778.101 | 11023.951 | 43802.1 |
| 45 | 16628.752 | 27182.699 | 43811.5 |
| 46 | 37127.990 | 6676.411 | 43804.4 |
| 47 | 34730.968 | 9066.383 | 43797.4 |
| 48 | 42213.437 | 1579.214 | 43792.7 |
| 49 | 41990.185 | 1837.717 | 43827.9 |
| 50 | 38241.901 | 5590.701 | 43832.6 |
| 51 | 36610.986 | 7191.066 | 43802.1 |
| 52 | 24444.924 | 19378.278 | 43823.2 |
| 53 | 41306.329 | 2533.323 | 43839.7 |
| 54 | 41945.535 | 1901.167 | 43846.7 |

| ID | Winter Wheat | Other | Total | ID | Winter Wheat | Other | Total |
|---|---|---|---|---|---|---|---|
| **55** | 29810.023 | 14001.428 | 43811.5 | **83** | 28597.412 | 15237.540 | 43835.0 |
| **56** | 40768.174 | 3059.728 | 43827.9 | **84** | 30475.079 | 13305.822 | 43780.9 |
| **57** | 38469.853 | 5325.149 | 43795.0 | **85** | 43804.402 | 0.000 | 43804.4 |
| **58** | 30529.130 | 13305.822 | 43835.0 | **86** | 31896.842 | 11909.909 | 43806.8 |
| **59** | 37529.844 | 6305.108 | 43835.0 | **87** | 41400.330 | 2401.722 | 43802.1 |
| **60** | 0.000 | 43816.152 | 43816.2 | **88** | 34587.617 | 9237.935 | 43825.6 |
| **61** | 29929.874 | 13876.877 | 43806.8 | **89** | 31250.587 | 12558.515 | 43809.1 |
| **62** | 39647.214 | 4190.088 | 43837.3 | **90** | 35520.576 | 8323.776 | 43844.4 |
| **63** | 40681.223 | 3130.229 | 43811.5 | **91** | 42810.343 | 1026.959 | 43837.3 |
| **64** | 25826.737 | 16236.299 | 42063.0 | **92** | 43071.195 | 728.507 | 43799.7 |
| **65** | 39705.964 | 2373.522 | 42079.5 | **93** | 35403.075 | 8413.077 | 43816.2 |
| **66** | 43477.749 | 314.903 | 43792.7 | **94** | 43792.652 | 0.000 | 43792.7 |
| **67** | 37454.643 | 6366.208 | 43820.9 | **95** | 35732.078 | 8086.424 | 43818.5 |
| **68** | 34268.014 | 9555.188 | 43823.2 | **96** | 42119.436 | 1656.765 | 43776.2 |
| **69** | 38568.554 | 5233.498 | 43802.1 | **97** | 31053.185 | 12786.467 | 43839.7 |
| **70** | 40573.122 | 3231.280 | 43804.4 | **98** | 41407.380 | 2382.922 | 43790.3 |
| **71** | 24931.379 | 18898.873 | 43830.3 | **99** | 43183.996 | 643.906 | 43827.9 |
| **72** | 28580.962 | 15246.940 | 43827.9 | **100** | 32420.897 | 11409.355 | 43830.3 |
| **73** | 31567.839 | 12271.813 | 43839.7 | **101** | 19843.582 | 23937.319 | 43780.9 |
| **74** | 38079.749 | 5722.302 | 43802.1 | **102** | 42514.240 | 1299.562 | 43813.8 |
| **75** | 40328.720 | 3468.632 | 43797.4 | **103** | 37377.093 | 6455.509 | 43832.6 |
| **76** | 40826.924 | 3003.328 | 43830.3 | **104** | 26595.194 | 17223.308 | 43818.5 |
| **77** | 35419.525 | 8354.327 | 43773.9 | **105** | 39992.667 | 3802.335 | 43795.0 |
| **78** | 38949.257 | 4852.794 | 43802.1 | **106** | 41186.478 | 2610.874 | 43797.4 |
| **79** | 35706.227 | 8133.425 | 43839.7 | **107** | 9432.986 | 34369.065 | 43802.1 |
| **80** | 37308.942 | 6504.860 | 43813.8 | **108** | 41130.077 | 2669.624 | 43799.7 |
| **81** | 40810.474 | 2972.777 | 43783.3 | **109** | 42298.038 | 1499.314 | 43797.4 |
| **82** | 41607.132 | 2225.470 | 43832.6 | **110** | 40561.372 | 3240.680 | 43802.1 |

| ID | Winter Wheat | Other | Total | ID | Winter Wheat | Other | Total |
|---|---|---|---|---|---|---|---|
| **111** | 39752.965 | 4030.287 | 43783.3 | **139** | 36289.033 | 7529.469 | 43818.5 |
| **112** | 38314.751 | 5506.100 | 43820.9 | **140** | 42612.941 | 1217.311 | 43830.3 |
| **113** | 37518.094 | 6307.458 | 43825.6 | **141** | 40956.176 | 2843.526 | 43799.7 |
| **114** | 39863.416 | 3962.136 | 43825.6 | **142** | 40638.923 | 3144.329 | 43783.3 |
| **115** | 28823.014 | 14990.787 | 43813.8 | **143** | 41759.883 | 2051.569 | 43811.5 |
| **116** | 37323.042 | 6467.259 | 43790.3 | **144** | 37727.246 | 6084.206 | 43811.5 |
| **117** | 37189.091 | 6624.711 | 43813.8 | **145** | 20485.138 | 23286.364 | 43771.5 |
| **118** | 37280.742 | 6516.610 | 43797.4 | **146** | 42206.387 | 1590.965 | 43797.4 |
| **119** | 40502.621 | 3311.180 | 43813.8 | **147** | 42439.039 | 1348.912 | 43788.0 |
| **120** | 40892.725 | 2909.327 | 43802.1 | **148** | 43122.895 | 690.906 | 43813.8 |
| **121** | 41708.182 | 2091.519 | 43799.7 | **149** | 40152.468 | 3666.034 | 43818.5 |
| **122** | 41809.233 | 2023.369 | 43832.6 | **150** | 42283.938 | 1508.714 | 43792.7 |
| **123** | 43339.097 | 479.404 | 43818.5 | **151** | 34117.613 | 9679.739 | 43797.4 |
| **124** | 23446.165 | 20332.386 | 43778.6 | **152** | 42126.486 | 1668.515 | 43795.0 |
| **125** | 22532.007 | 21305.295 | 43837.3 | **153** | 36227.932 | 7595.270 | 43823.2 |
| **126** | 42587.091 | 1212.611 | 43799.7 | **154** | 40406.271 | 3398.131 | 43804.4 |
| **127** | 41550.731 | 2246.621 | 43797.4 | **155** | 30667.781 | 13113.120 | 43780.9 |
| **128** | 41193.528 | 2594.424 | 43788.0 | **156** | 28649.113 | 15155.289 | 43804.4 |
| **129** | 39832.865 | 3964.486 | 43797.4 | **157** | 37435.843 | 6363.858 | 43799.7 |
| **130** | 29213.118 | 14614.784 | 43827.9 | **158** | 34373.765 | 9421.236 | 43795.0 |
| **131** | 41583.631 | 2244.271 | 43827.9 | **159** | 39983.267 | 3821.135 | 43804.4 |
| **132** | 36667.386 | 7141.715 | 43809.1 | **160** | 18123.366 | 25692.786 | 43816.2 |
| **133** | 30409.279 | 13385.723 | 43795.0 | **161** | 27502.302 | 16292.699 | 43795.0 |
| **134** | 34279.764 | 9512.887 | 43792.7 | **162** | 39334.661 | 4450.941 | 43785.6 |
| **135** | 33718.109 | 10105.093 | 43823.2 | **163** | 42356.788 | 1466.413 | 43823.2 |
| **136** | 39069.108 | 4728.243 | 43797.4 | **164** | 31074.335 | 12694.816 | 43769.2 |
| **137** | 39644.864 | 4157.188 | 43802.1 | **165** | 42688.141 | 1092.760 | 43780.9 |
| **138** | 41694.082 | 2117.369 | 43811.5 | **166** | 43773.851 | 0.000 | 43773.9 |

| ID | Winter Wheat | Other | Total |
|---|---|---|---|
| 167 | 41339.229 | 2460.473 | 43799.7 |
| 168 | 39414.561 | 4378.090 | 43792.7 |
| 169 | 31657.140 | 12166.062 | 43823.2 |
| 170 | 27920.606 | 15843.845 | 43764.5 |
| 171 | 42469.589 | 1332.462 | 43802.1 |
| 172 | 42439.039 | 1353.612 | 43792.7 |
| 173 | 36937.639 | 6878.513 | 43816.2 |
| 174 | 36437.084 | 7346.167 | 43783.3 |
| 175 | 42305.088 | 1504.014 | 43809.1 |
| 176 | 38509.803 | 5280.498 | 43790.3 |
| 177 | 32416.197 | 11357.654 | 43773.9 |
| 178 | 35978.830 | 7804.422 | 43783.3 |
| 179 | 36714.387 | 7085.315 | 43799.7 |
| 180 | 42138.236 | 1633.265 | 43771.5 |
| 181 | 43118.195 | 660.356 | 43778.6 |
| 182 | 38702.505 | 5101.897 | 43804.4 |
| 183 | 40883.325 | 2888.176 | 43771.5 |
| 184 | 42248.687 | 1562.764 | 43811.5 |
| 185 | 43804.402 | 0.000 | 43804.4 |
| 186 | 37790.697 | 6004.305 | 43795.0 |
| 187 | 40514.371 | 3271.230 | 43785.6 |
| 188 | 33598.258 | 10180.293 | 43778.6 |
| 189 | 42295.688 | 1492.264 | 43788.0 |
| 190 | 43581.150 | 223.252 | 43804.4 |
| 191 | 41153.577 | 2643.774 | 43797.4 |
| 192 | 41647.082 | 2117.369 | 43764.5 |
| 193 | 41200.578 | 2566.224 | 43766.8 |

***Table 2.18 The statistics of Guoyang Soybean and maize area in 2012***

Unit: $m^2$

| ID | Soybean | Maize | Other | Total |
|---|---|---|---|---|
| 1 | 41637.682 | 0.000 | 2199.620 | 43837 |
| 2 | 40540.222 | 0.000 | 3264.180 | 43804 |
| 3 | 36911.788 | 6260.457 | 669.756 | 43842 |
| 4 | 38183.150 | 0.000 | 5642.402 | 43826 |
| 5 | 26837.246 | 7162.866 | 9816.040 | 43816 |
| 6 | 15373.841 | 22480.306 | 5959.655 | 43814 |
| 7 | 36857.738 | 0.000 | 6932.564 | 43790 |
| 8 | 39435.712 | 0.000 | 4410.990 | 43847 |
| 9 | 31603.090 | 0.000 | 12187.212 | 43790 |
| 10 | 41325.129 | 0.000 | 2507.473 | 43833 |
| 11 | 493.505 | 38916.357 | 4427.441 | 43837 |
| 12 | 16553.552 | 2220.770 | 25032.430 | 43807 |
| 13 | 40519.072 | 573.405 | 2721.325 | 43814 |
| 14 | 36798.987 | 4497.941 | 2538.023 | 43835 |
| 15 | 8373.127 | 33285.705 | 2152.620 | 43811 |
| 16 | 31476.189 | 9148.634 | 3186.629 | 43811 |
| 17 | 26635.144 | 472.354 | 16708.653 | 43816 |
| 18 | 40902.125 | 0.000 | 2899.927 | 43802 |
| 19 | 20158.485 | 21890.451 | 1739.016 | 43788 |
| 20 | 38491.003 | 0.000 | 5327.499 | 43819 |
| 21 | 35706.227 | 3825.835 | 4298.189 | 43830 |
| 22 | 39557.913 | 733.207 | 3525.032 | 43816 |
| 23 | 34216.314 | 1539.264 | 8062.924 | 43819 |
| 24 | 29201.368 | 0.000 | 14617.134 | 43819 |
| 25 | 28872.365 | 0.000 | 14927.337 | 43800 |
| 26 | 35196.273 | 169.202 | 8448.327 | 43814 |

| ID | Soybean | Maize | Other | Total |
|---|---|---|---|---|
| 27 | 38566.204 | 1741.366 | 3480.382 | 43788 |
| 28 | 32825.101 | 4742.343 | 6260.457 | 43828 |
| 29 | 39329.961 | 0.000 | 4504.991 | 43835 |
| 30 | 41395.630 | 0.000 | 2446.372 | 43842 |
| 31 | 40293.469 | 0.000 | 3541.482 | 43835 |
| 32 | 25685.736 | 526.405 | 17578.161 | 43790 |
| 33 | 40631.873 | 0.000 | 3198.379 | 43830 |
| 34 | 43238.046 | 0.000 | 571.055 | 43809 |
| 35 | 38695.455 | 918.858 | 4180.688 | 43795 |
| 36 | 41618.882 | 0.000 | 2206.670 | 43826 |
| 37 | 35426.575 | 0.000 | 8363.727 | 43790 |
| 38 | 18130.416 | 991.709 | 24729.277 | 43851 |
| 39 | 39062.058 | 1414.713 | 3362.881 | 43840 |
| 40 | 9663.289 | 29755.973 | 4415.690 | 43835 |
| 41 | 26183.940 | 14755.785 | 2899.927 | 43840 |
| 42 | 41374.479 | 1562.764 | 850.708 | 43788 |
| 43 | 39879.866 | 3092.628 | 862.458 | 43835 |
| 44 | 1539.264 | 30945.084 | 11317.704 | 43802 |
| 45 | 9879.491 | 6749.262 | 27182.699 | 43811 |
| 46 | 34855.520 | 0.000 | 8948.882 | 43804 |
| 47 | 34730.968 | 0.000 | 9066.383 | 43797 |
| 48 | 41987.835 | 225.602 | 1579.214 | 43793 |
| 49 | 41428.530 | 556.955 | 1842.417 | 43828 |
| 50 | 25476.584 | 12765.317 | 5590.701 | 43833 |
| 51 | 30176.627 | 6434.359 | 7191.066 | 43802 |
| 52 | 23587.166 | 876.558 | 19359.478 | 43823 |
| 53 | 41306.329 | 0.000 | 2533.323 | 43840 |
| 54 | 41945.535 | 0.000 | 1901.167 | 43847 |

| ID | Soybean | Maize | Other | Total |
|---|---|---|---|---|
| 55 | 23483.765 | 6314.508 | 14013.178 | 43811 |
| 56 | 40768.174 | 0.000 | 3059.728 | 43828 |
| 57 | 38469.853 | 0.000 | 5325.149 | 43795 |
| 58 | 25880.787 | 4648.343 | 13305.822 | 43835 |
| 59 | 26651.594 | 10878.250 | 6305.108 | 43835 |
| 60 | 0.000 | 0.000 | 43816.152 | 43816 |
| 61 | 29116.767 | 733.207 | 13956.778 | 43807 |
| 62 | 39647.214 | 0.000 | 4190.088 | 43837 |
| 63 | 35579.326 | 5101.897 | 3130.229 | 43811 |
| 64 | 22865.710 | 9101.633 | 10095.693 | 42063 |
| 65 | 25941.888 | 13764.076 | 2373.522 | 42079 |
| 66 | 43447.198 | 0.000 | 345.453 | 43793 |
| 67 | 33908.461 | 3532.082 | 6380.309 | 43821 |
| 68 | 33297.455 | 970.559 | 9555.188 | 43823 |
| 69 | 38568.554 | 0.000 | 5233.498 | 43802 |
| 70 | 39541.463 | 1833.017 | 2429.922 | 43804 |
| 71 | 22717.658 | 2213.720 | 18898.873 | 43830 |
| 72 | 33718.109 | 3031.528 | 7078.265 | 43828 |
| 73 | 31497.339 | 70.501 | 12271.813 | 43840 |
| 74 | 33854.410 | 4225.339 | 5722.302 | 43802 |
| 75 | 40331.070 | 0.000 | 3466.282 | 43797 |
| 76 | 36925.889 | 0.000 | 6904.363 | 43830 |
| 77 | 32061.344 | 3358.181 | 8354.327 | 43774 |
| 78 | 38949.257 | 0.000 | 4852.794 | 43802 |
| 79 | 35217.423 | 488.804 | 8133.425 | 43840 |
| 80 | 35029.421 | 2279.521 | 6504.860 | 43814 |
| 81 | 39120.809 | 1689.665 | 2972.777 | 43783 |
| 82 | 41607.132 | 0.000 | 2225.470 | 43833 |

| ID | Soybean | Maize | Other | Total |
|---|---|---|---|---|
| 83 | 26270.891 | 2326.521 | 15237.540 | 43835 |
| 84 | 30475.079 | 1099.810 | 12206.012 | 43781 |
| 85 | 43804.402 | 0.000 | 0.000 | 43804 |
| 86 | 30827.583 | 0.000 | 12979.169 | 43807 |
| 87 | 40643.623 | 756.707 | 2401.722 | 43802 |
| 88 | 32101.294 | 2427.572 | 9296.685 | 43826 |
| 89 | 31250.587 | 0.000 | 12558.515 | 43809 |
| 90 | 35520.576 | 0.000 | 8323.776 | 43844 |
| 91 | 41898.534 | 911.808 | 1026.959 | 43837 |
| 92 | 43071.195 | 0.000 | 728.507 | 43800 |
| 93 | 35403.075 | 0.000 | 8413.077 | 43816 |
| 94 | 43505.949 | 0.000 | 286.703 | 43793 |
| 95 | 35473.575 | 0.000 | 8344.927 | 43819 |
| 96 | 42119.436 | 0.000 | 1656.765 | 43776 |
| 97 | 29986.275 | 0.000 | 13853.377 | 43840 |
| 98 | 36552.235 | 3799.985 | 3438.082 | 43790 |
| 99 | 35309.074 | 7874.922 | 643.906 | 43828 |
| 100 | 31833.392 | 0.000 | 11996.860 | 43830 |
| 101 | 20811.791 | 1139.760 | 21829.350 | 43781 |
| 102 | 42514.240 | 0.000 | 1299.562 | 43814 |
| 103 | 32390.347 | 4986.746 | 6455.509 | 43833 |
| 104 | 26595.194 | 0.000 | 17223.308 | 43819 |
| 105 | 39912.766 | 0.000 | 3882.236 | 43795 |
| 106 | 11475.155 | 29711.322 | 2610.874 | 43797 |
| 107 | 9432.986 | 0.000 | 34369.065 | 43802 |
| 108 | 41130.077 | 0.000 | 2669.624 | 43800 |
| 109 | 42298.038 | 0.000 | 1499.314 | 43797 |
| 110 | 40561.372 | 0.000 | 3240.680 | 43802 |

| ID | Soybean | Maize | Other | Total |
|---|---|---|---|---|
| 111 | 14429.132 | 25323.832 | 4030.287 | 43783 |
| 112 | 24567.125 | 13747.626 | 5506.100 | 43821 |
| 113 | 37518.094 | 0.000 | 6307.458 | 43826 |
| 114 | 39936.266 | 0.000 | 3889.286 | 43826 |
| 115 | 18804.872 | 183.302 | 24825.628 | 43814 |
| 116 | 36686.186 | 0.000 | 7104.115 | 43790 |
| 117 | 36448.834 | 1424.113 | 5940.854 | 43814 |
| 118 | 36751.987 | 411.254 | 6634.111 | 43797 |
| 119 | 39980.917 | 521.705 | 3311.180 | 43814 |
| 120 | 40892.725 | 0.000 | 2909.327 | 43802 |
| 121 | 41708.182 | 0.000 | 2091.519 | 43800 |
| 122 | 41809.233 | 0.000 | 2023.369 | 43833 |
| 123 | 43339.097 | 0.000 | 479.404 | 43819 |
| 124 | 22971.461 | 474.704 | 20332.386 | 43779 |
| 125 | 22532.007 | 0.000 | 21305.295 | 43837 |
| 126 | 42587.091 | 0.000 | 1212.611 | 43800 |
| 127 | 41341.579 | 390.104 | 2065.669 | 43797 |
| 128 | 41193.528 | 0.000 | 2594.424 | 43788 |
| 129 | 39832.865 | 0.000 | 3964.486 | 43797 |
| 130 | 22327.555 | 6885.563 | 14614.784 | 43828 |
| 131 | 40450.921 | 1132.710 | 2244.271 | 43828 |
| 132 | 36667.386 | 0.000 | 7141.715 | 43809 |
| 133 | 22085.503 | 8323.776 | 13385.723 | 43795 |
| 134 | 30143.726 | 4389.840 | 9259.085 | 43793 |
| 135 | 32263.446 | 0.000 | 11559.756 | 43823 |
| 136 | 38648.454 | 0.000 | 5148.897 | 43797 |
| 137 | 40878.625 | 0.000 | 2923.427 | 43802 |
| 138 | 41694.082 | 0.000 | 2117.369 | 43811 |

| ID | Soybean | Maize | Other | Total |
|---|---|---|---|---|
| 139 | 36289.033 | 0.000 | 7529.469 | 43819 |
| 140 | 42521.290 | 0.000 | 1308.962 | 43830 |
| 141 | 40956.176 | 0.000 | 2843.526 | 43800 |
| 142 | 40613.072 | 0.000 | 3170.179 | 43783 |
| 143 | 39720.064 | 2051.569 | 2039.819 | 43811 |
| 144 | 35823.728 | 1821.267 | 6030.155 | 43675 |
| 145 | 18736.722 | 5421.500 | 19613.280 | 43772 |
| 146 | 37130.340 | 3003.328 | 3663.684 | 43797 |
| 147 | 42439.039 | 0.000 | 1348.912 | 43788 |
| 148 | 43122.895 | 0.000 | 690.906 | 43814 |
| 149 | 40152.468 | 0.000 | 3666.034 | 43819 |
| 150 | 42283.938 | 0.000 | 1508.714 | 43793 |
| 151 | 34117.613 | 0.000 | 9679.739 | 43797 |
| 152 | 42126.486 | 0.000 | 1668.515 | 43795 |
| 153 | 35443.025 | 1001.109 | 7379.068 | 43823 |
| 154 | 35992.930 | 4413.340 | 3398.131 | 43804 |
| 155 | 19422.928 | 11240.153 | 13117.820 | 43781 |
| 156 | 10246.094 | 18403.019 | 15155.289 | 43804 |
| 157 | 37435.843 | 0.000 | 6363.858 | 43800 |
| 158 | 34834.369 | 324.303 | 8636.329 | 43795 |
| 159 | 39983.267 | 0.000 | 3821.135 | 43804 |
| 160 | 18123.366 | 0.000 | 25692.786 | 43816 |
| 161 | 27502.302 | 0.000 | 16292.699 | 43795 |
| 162 | 39334.661 | 0.000 | 4450.941 | 43786 |
| 163 | 42079.486 | 0.000 | 1743.716 | 43823 |
| 164 | 30235.377 | 838.958 | 12694.816 | 43769 |
| 165 | 42688.141 | 0.000 | 1092.760 | 43781 |
| 166 | 43773.851 | 0.000 | 0.000 | 43774 |
| 167 | 41332.179 | 0.000 | 2467.523 | 43800 |
| 168 | 39872.816 | 0.000 | 3919.836 | 43793 |
| 169 | 31478.539 | 0.000 | 12344.663 | 43823 |
| 170 | 26064.089 | 0.000 | 17700.362 | 43764 |
| 171 | 42469.589 | 0.000 | 1332.462 | 43802 |
| 172 | 42439.039 | 0.000 | 1353.612 | 43793 |
| 173 | 37106.840 | 0.000 | 6709.312 | 43816 |
| 174 | 35153.972 | 0.000 | 8629.279 | 43783 |
| 175 | 42575.340 | 0.000 | 1233.761 | 43809 |
| 176 | 3633.133 | 33532.457 | 6624.711 | 43790 |
| 177 | 32416.197 | 0.000 | 11357.654 | 43774 |
| 178 | 30754.732 | 5224.098 | 7804.422 | 43783 |
| 179 | 29260.118 | 7454.268 | 7085.315 | 43800 |
| 180 | 42138.236 | 0.000 | 1633.265 | 43772 |
| 181 | 43118.195 | 0.000 | 660.356 | 43779 |
| 182 | 39527.362 | 0.000 | 4277.039 | 43804 |
| 183 | 39898.666 | 0.000 | 3872.836 | 43772 |
| 184 | 42248.687 | 0.000 | 1562.764 | 43811 |
| 185 | 43804.402 | 0.000 | 0.000 | 43804 |
| 186 | 37790.697 | 0.000 | 6004.305 | 43795 |
| 187 | 36516.985 | 3997.387 | 3271.230 | 43786 |
| 188 | 33598.258 | 0.000 | 10180.293 | 43779 |
| 189 | 42295.688 | 0.000 | 1492.264 | 43788 |
| 190 | 43581.150 | 0.000 | 223.252 | 43804 |
| 191 | 41153.577 | 0.000 | 2643.774 | 43797 |
| 192 | 40906.825 | 740.257 | 2117.369 | 43764 |
| 193 | 41200.578 | 0.000 | 2566.224 | 43767 |

# 3 THE CROP AREA SPATIAL EXTRAPOLATION MODEL

Because the sampling fraction of Guoyang was too small, the ground sampling units were used for interpretation and validation. The spatial extrapolation model of Guoyang County had been build. The details will be described in the D51.2. Here we summarise the essence of the approach.

## 3.1 The spatial extrapolation model

The specific process is to calculate the average value of crop area within samples and total samples separately. The total crop area of Guoyang county are calculated by multiplying the above two value. In the calculation process, assuming the mean value of the ground sampling units is approximately equal to the mean value of the population. This assumption will be discussed further in the following research.

According to the steps of design of ground sampling units, the calculation formula is as follows：

$$\bar{s}_w = \sum_{i=1}^{193} s_i \tag{3.1}$$

$$N = \frac{S_{county}}{S_c} \times 83.5\% \tag{3.2}$$

$$\hat{S} = \bar{s}_w \times N \tag{3.3}$$

where,

$s_i$ is area of target crop of each ground sample;

$\bar{s}_w$ is the average value of crop area of all ground samples;

N is total samples of crops;

$S_{county}$ is total area of Guoyang county;

$S_c$ is the mean area of ground sampling units;

$\hat{S}$ is the total area of crops;

83.5% is a coefficient which is calculated in the third step of the sampling unit design. It means that 83.5% of total area is cropland in Guoyang county.

## 3.2 Accuracy assessment on the spatial extrapolation

The measurement results of 193 ground samples were utilized to extrapolate the main crop area of Guoyang county. By using above Model, the extrapolation of winter wheat, soybean, and maize area of 2012 was conducted, and the result of the extrapolation is illustrated as follows:

***Table3.1 Extrapolation result of 2012 main crop area of Guoyang county***

| Crop | Total Area (kha) | Hard Classification result (k ha) |
|---|---|---|
| **Winter Wheat** | 148.61 | 148.95 |
| **Soybean** | 136.79 | 143.31 |
| **Maize** | 11.73 | 10.16 |

The hard classification result of the winter wheat area was extracted from RapidEye image using SAM classifier. The area of soybean and maize was extracted from Liss3 image using NN classifier. Because many tree and other land-cover were misclassified as maize. So we used the result of ground sampling units and the result of visual interpretation to modified the result of the maize area.

Relative error (r) and coefficient of variation of population total estimator (CV) are selected as indices to evaluate the results of population extrapolation and error estimation. Relative error and CV are calculated according to (3.4) and (3.5), respectively.

$$r = \frac{|S-\hat{S}|}{S} \times 100\% \tag{3.4}$$

$$CV(\hat{S}) = \frac{\sqrt{v(\hat{S})^2}}{\hat{S}} \times 100\% \tag{3.5}$$

Where *S* is the truth value of population total, which is hard classification result extracted from remote sensing data. $CV(\hat{S})$ is coefficient of variation of population total estimator. Table 3.2 shows the relative error (*r*) and $CV(\hat{S})$ of main crop area.

***Table3.2 Relative error (r) and $CV(\hat{S})$ of 2012 main crop area***

| Crop | Relative error (*r*) % | $CV(\hat{S})$ |
|---|---|---|
| **Winter Wheat** | 0.23 | 3.10 |
| **Soybean** | 4.55 | 6.56 |
| **Maize** | 15.45 | 76.49 |

It is found that the relative error and CV of winter wheat area are less than 5%. For soybean area, the relative error is small but the CV is more than 5%. For maize area, the relative error and CV are higher.

# 4 CONCLUSIONS

In Mengcheng County, the ground sampling units were designed based on grid-based random sampling method. All units has physical boundaries. We surveyed 83 units. The average area of units was 29.77 hectare. Every day we could investigate 4-6 units. Because the number of units was too small, the ground sampling units only used as validation data. In the next study, we will further explore the optimal number and size of ground sampling unit, and build the crop area extrapolation model based on the ground sampling units with physical boundaries.

In Guoyang County, the ground sampling units were designed based on systematic sampling. A total of 193 sampling units were selected according to the rule of sampling at equal interval. Every sampling unit had circle boundary. The average area of each unit was 4.62 hectare. Combined with the physical boundary, all ground sampling units have the same size and shape. It can help us to save the field survey time, at the same time can accurately calculate the number of total samples. Field survey was conducted in April and July, respectively, each less than 20 days.

The spatial extrapolation model and the sampling fraction is suitable for calculated the area of winter wheat and soybean. Each crop area accounted for 60% of the of Guoyang total area. This conclusion requires further verification. For maize area, the relative error and CV is too high. One reason is that maize area was less than 10% of total area of Guoyang area. The ground sampling units and the spatial extrapolation model need to be redesigned.

In conclusion, the approach of ground sampling applied in Guoyang has a relative high time efficiency in comparison with what was applied in Mengcheng. However this temporal efficiency was obtained at expenses of the estimation accuracy. A third approach will be designed and applied in the third implementation year and a cost efficiency analysis will be made and described in the deliverable D55.1.