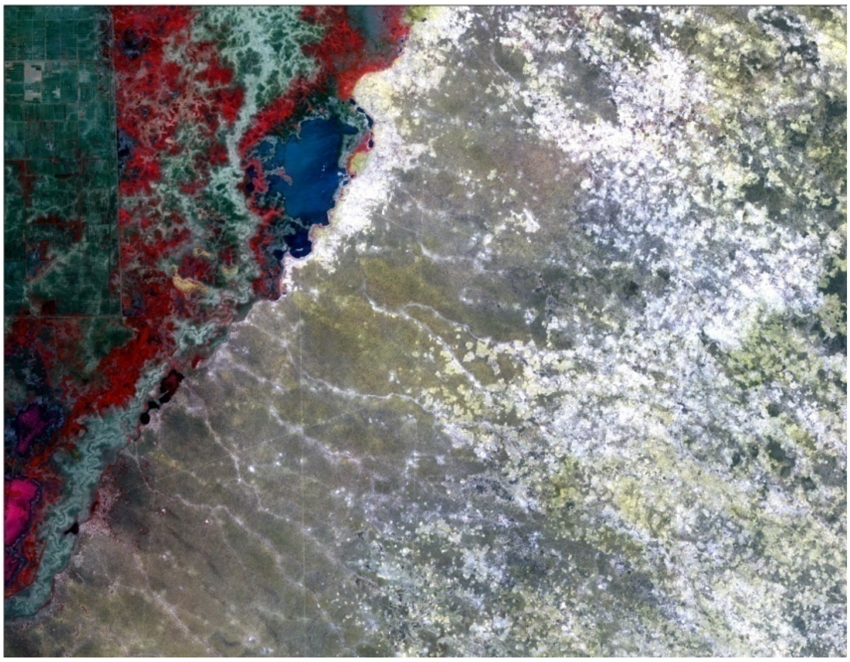
ESTIMATING CULTIVABLE AREAS IN CENTRAL AND SOUTHERN SOMALIA USING REMOTE SENSING



Technical Report No. RSM-02

November 2012

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Funded by the European Union and implemented by the Food and Agriculture Organization of the United Nations

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This document should be cited as follows:
Oduori, S. M., Oroda A. S., Gadain H., and F. Rembold, 2012: Estimating Cultivable Areas in Central and Southern Somalia using Remote Sensing by FAO-SWALIM. **Project Report No. RSM 02** Nairobi, Kenya.

ACKNOWLEDGMENTS

We would like to give special thanks to Sergio Innocente, Thomas Gabriel, Dario Cipolla, Tamara Nanitashvili, and Jeremiah Njeru for their technical thoughts and support that led to the formulation and implementation of this work.

Many thanks and acknowledge to the United States Geological Survey (USGS) who provided (free of charge) the ASTER and Landsat images that were instrumental in the implementation of this work. We are, particularly grateful to Messrs James Roland and Michael (Mike) Budde, both of USGS, who facilitated the provision of the satellite images and Dr. Hussein Gadain for the good link with USGS. We are also grateful to the Joint Research Centre (JRC) who provided supplementary images and technical support during the implementation of this work. The images were provided by Andreas Brink of the MONDE action, while technical inputs for the definition of the sampling scheme were received from Olivier Leo and Javier Gallego of the MARS Unit. The Landsat images were originally obtained free of charge from the Global Land Survey (GLS) partnership between USGS and NASA (http://gls/umd.edu).

We are grateful to, and acknowledge the immense contributions from our colleagues at FAO-SWALIM, especially John Mwanzia and Mary Cherono for image interpretation, Mr. Antony Ndubi for his tireless efforts in processing and providing all the necessary images required for this work and all the other staff involved, especially Dr. Hussein Gadain, James Ngochoch, and Margaret Mugo for their technical contributions as well as moral support that made the implementation of this exercise a success. We also wish to acknowledge the technical support from Ms. Julie Maingi of the Regional Centre for Mapping of Resources for Development (RCMRD) who conducted training on the Rapid Land Cover Mapper methodology at the inception of this exercise, and final editing of all the district maps. Zoltan Balint, Chief Technical Advisor, SWALIM for technical advise, logistical support and professional input.

Lastly, many thanks go to Dr. Luca Alinovi, the Officer in Charge of FAO-Somalia for his technical and financial support.

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1. INTRODUCTION

1.1. Background

Somalia is largely a hot, arid and semi-arid country with rainfall amounts averaging between 50 and 500 - 600 mm per annum (even though some areas may receive slightly higher amounts). The prolonged civil war which culminated in the fall of the Somali Government in 1991 and the subsequent lack of a functional government led to a situation of dysfunctional public institutions. This has subjected the country to extreme environmental degradation both natural and man-made. The subsequent economic crisis coupled with high population pressure, competition over limited resources and poverty have resulted in ecosystems and natural resources destruction that has affected survival and well-being (Omuto *et al* 2007). Livestock is the main source of income for most Somalis, while agriculture is concentrated mainly in the South along and between the two main rivers of Shabelle and Juba.

1.2. Rationale

The Food and Agriculture Organization (FAO) is supporting smallholder farmers in the whole of Somalia through a large number of rural development projects but due to insecurity and accessibility difficulties, the information on agriculture in Somalia is mainly based on oral tradition, assumptions, rough estimates and historical data. Most of these data are inaccurate and in a number of cases obsolete. To support FAO and other institutions agricultural interventions, there is a need to know, based on actual data, the total cultivable land in Somalia, especially in the southern and central regions where agricultural activities are concentrated.

Ideally, agricultural area should be assessed for each crop season in order to make available exact agricultural statistics for further analysis such as production estimation and for planning of rural development projects. However, at an assumed cost for VHR archive imagery of 18USD/sqkm, the image acquisition only would cost already 3,6 Mio. USD for Southern Somalia only. Furthermore recent investigations of SWALIM and partners on the availability of VHR imagery for Southern Somalia led to the results that only a limited fraction of the country is covered every year by VHR imagery.

For these reasons it was decided to work with medium resolution images like ASTER and Landsat. This choice lead also to a redefinition of the areas to be monitored, which do not correspond to annual or seasonal crop areas, but more to areas cultivated during any season in the recent history.

Cultivable areas in this context refer to areas that have been cultivated at least once in the last 4 years, irrespective of whether they were cropped at the time of the survey. Areas that have the soil, topographical and other characteristics that would make cultivation possible, but have never been actually incorporated in the agricultural production in this time span have not been included in this survey. The 4 years period was chosen because it corresponds to the maximum length of time during which the traces of cultivation such as clearing, field demarcations and shapes are expected to remain visible in a semi arid area such as most of Southern Somalia. This implies that the total cultivable area identified in this study is actually larger than the land cultivated during a single season. It includes also the fallow areas and is therefore close to the total arable land with exclusion of the rangeland areas.

To provide a first estimate of the cultivable land, this study analyzed ASTER satellite images (and where not available, other medium resolution images) for 2010 and 2011 to generate information about cultivation in central and southern Somalia. The results of this study will be the basis for a successive, more accurate analysis which will include sampling approaches and field validation (through FAO emergency staff and FSNAU monitors) in order to establish the potential cultivable land and estimate production for the different cropping systems at farmer and district levels.

Information on cultivable land and cropping patterns will support decision making on agricultural programme design for different regions/districts bearing in mind the major agricultural production limiting factors among them land, labour, water, capital, farmer and market organizations. This information is also crucial for planning agricultural input distribution, cash for work and other interventions for both emergency and regular programmes. In addition the information generated will be a reference data source in an agricultural system where most of the seasonal assessment results are based on rapid surveying techniques, more similar to CFSAM methods than to statistical surveys.

1.3. Objectives of the study

The main objective of the activity was to provide an estimate of the cultivable area in Southern Somalia. The error of the estimate should be statically measurable, as opposed to the agricultural area figures available since the start of the civil conflict in Somalia, whose accuracy cannot be quantitatively assessed.

The second objective was to create a land cover/land use map. However, the mapping accuracy was of a lower priority as compared to area statistics as explained in the methodological section.

2. METHODOLOGY

2.1. The study area

The study area comprises 36 administrative districts located in 8 regions covering the central and southern parts of Somalia as shown in Figure 1. The regions are Hiran, Bakool, Gedo, Bay, Middle Shabelle, Lower Shabelle, Middle Juba and Lower Juba. The area covers the Middle and Lower Juba and Shabelle Rivers, which comprise the main agricultural areas of Somalia. The total area is 256,590 km^2 (or 25,659,056 Hectares). This area includes the main agricultural zones of Southern and Central Somalia, including the rainfed sorghum production areas of Bay and Bakool and the typically irrigated maize producing areas along the Juba and Shabelle rivers. A significant portion of the irrigated areas bordering the Shabelle and Juba rivers had already been photo interpreted by SWALIM in 2008 but the current study is the first attempt to cover the whole agricultural area.

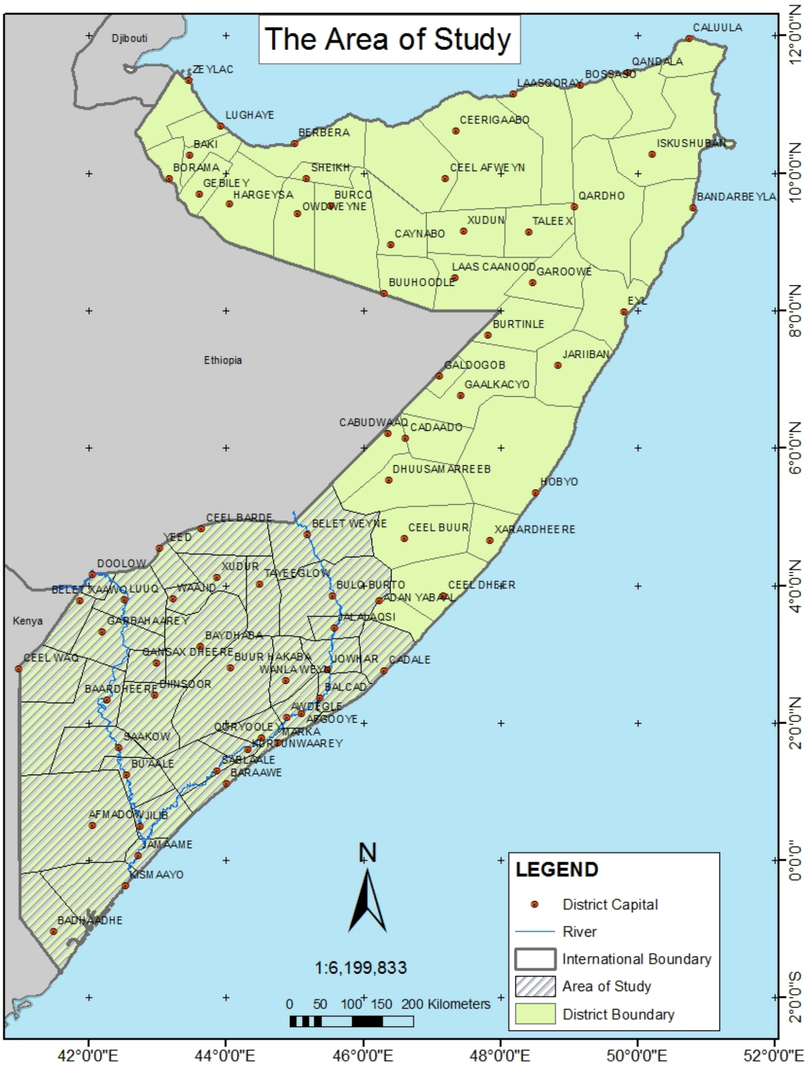


Figure 1: Map of the study area

The study covered an area of 256,590 km^2 (or 25,659,056 Hectares).

Climate

Somalia in general has an arid to semi-arid climate, with substantial localised differences throughout the country and areas with tropical arid to dry and sub-humid in the river basins. The climate in Somalia is influenced by the north-easterly and south-easterly air flows of the Intertropical Convergence Zone (ITCZ). North-easterly and south-easterly air masses meet in the Intertropical Front (ITF) and raise air upwards to produce rain. The annual movements of the ITCZ from north to south across Africa and back again, give rise to four different seasons in Somalia, comprising two distinguishable rainy seasons alternating with two marked dry seasons, as follows:

- *Gu*: April to June, the main rainy season for all over the country
- *Xagaa*: July to September, littoral showers, but dry and cool in the hinterland
- *Deyr*: October to December, second rainy season for all over the country
- *Jilaal*: January to March, longer dry season for all over the country

Rainfall in the study area is erratic, with a bimodal pattern except in the southern riverine areas close to the coast where some showers may occur even during the *Xagaa*. Rainfall varies considerably over the study area, with the *Gu* delivering about 60% of total mean annual rainfall. Total mean annual rainfall ranges from 200 - 400 mm in areas bordering Ethiopia in Hiiraan, Gedo and Bakool regions and 400 - 500 mm in the central Bay and northern part of Middle and Lower Shabelle Regions. Higher rainfall areas receiving more than 600 mm occur in the Middle Jubba region, around Jilib in the southern riverine areas. Rainfall is characterised by intense, short rainstorms. The study area has a high inter-annual rainfall variation and is subject to recurrent drought every 3-4 years, and more severe dry periods every 7-9 years.

Air temperatures are influenced by altitude and by the strength of seasonal winds. In the first dry season (*Xagaa*) days are often cool and cloudy all over the region, with light showers in areas close to the coast. In the second dry season (*Jilaal*) days are hot, or very hot and dry. However, the hottest period coincides with the months of March and April.

Temperatures vary with the seasons, with the mean annual temperature ranging from 23°-30°C, with a maximum temperature of 41°C in March (Baardheere) and a minimum temperature of 24°C in July. In areas near the major rivers the relative humidity is high, ranging from about 70-80%, but further inland away from the rivers the air is much drier. Relative humidity is higher in the coastal areas, where it usually exceeds 87%. Normally, the high relative humidity is compounded by higher temperatures.

The major winds are in response to the north and south seasonal movement of the Inter-tropical Convergence Zone, and in particular the Inter-tropical front. In the study area the winds persistently blow from the northeast during *Jilaal* (December to February), when the weather is hot or very hot, and from the southwest during *Xagaa*, (June to August), when the weather is cool and cloudy.

The weather is hot and calm between the monsoons (part or whole of April and part or whole of September). In the *Jilaal* periods, prevailing winds are strong and blow in heavy dust storms from the Arabian Peninsula. Weaker winds generally occur during the inter-monsoonal periods of April/May and October/November. Average wind speed varies between 2-6m per second.

Landform/Soils

According to the bibliography, the study area is characterized by the following land features:

1. The two main river valleys (Jubba and Shabelle Rivers) that traverse the generally level, undulating morphology of the area;
2. hilly topography in the middle of the study area cut by wadis, and gently undulating wide plains toward the coast; and
3. a coastal dune complex known as the Merka red dunes, which fringes the coast from beyond the Kenyan border, separating the narrow coastal belt from the Webi Shebeli alluvial plain (Carbone & Accordi, 2000).

The study area is dominated by the presence of the distal portion of the two main perennial rivers of the Horn of Africa, flowing from the highlands of Ethiopia towards the Indian Ocean: the Jubba River (700 km of which are within Somalia, out of its 2 000 km total length) and the Shabelle River (1 560 km of which are within Somalia, out of its almost 1 800 km total length). The Jubba flows into the Indian Ocean close to Kismaayo city, while the Shabelle impounds itself a few kilometres before reaching the lower tract of the Jubba.

Because of the predominance of alluvium, many soils comprise layers of deposited materials which, because of the semi-arid climate, have been little-affected by normal soil-forming processes. Despite their variability, most soils share the characteristics of heavy texture and low permeability, with a tendency to poor drainage.

Prominent in Southern Somalia are low-lying alluvial plains, associated with the Juba and Shabelle rivers. These plains mainly have clayey soils, some of which have poor drainage and/or high content of salts. Some of the riverine areas are also liable to flooding. The inter-riverine areas have both shallow soils (particularly towards the border with Ethiopia) and deep loamy and clayey soils.

Land Cover

Land cover in the study area consists mainly of natural vegetation. Other cover types include Crop fields (both rainfed and irrigated), Urban and Associated Areas (Settlement/Towns and Airport), Dunes and Bare lands and Natural Water bodies. The natural vegetation consists of riparian forest, bush lands and grasslands. Woody and herbaceous species include *Acacia bussei, A. seyal, A. nilotica, A. tortilis, A. senegal, Chrysopogon auchieri* var. *quinqueplumis, Suaeda fruticosa* and *Salsola foetida*.

Land Use

Land use in the study area consists mainly of grazing and wood collection for fuel and building material. Rangelands in the Jubba and Shabelle catchments support livestock such as goats, sheep, cattle and camels. Livestock ownership is private, but grazing lands are communal, making it very difficult to regulate range use. Rangelands are utilised by herders using transhumance strategies (Shaie, 1997). Land cover associated with this land use includes forest, bushlands and grasslands (GTZ, 1990).

Rainfed agriculture includes crops like sorghum, millet, maize, groundnuts, cowpeas, mung beans, cassava and other minor crops, and are grown twice a year in the *Gu* and *Deyr* seasons. Small-scale irrigated fields are also found along the Shabelle and Jubba river valleys, growing maize, sesame, fruit trees and vegetables while large-scale plantations include sugar cane, bananas, guava, lemon, mango and papaya.

Flood recession cultivation in *desheks* (natural depressions) on the Jubba River floodplain is common, crops including sesame, maize and vegetables. Major crops in the *desheks* are maize, sesame, tobacco, beans, peas and vegetables, watermelon and (rarely) groundnuts. Cropping is either single or mixed.

2.2. Materials

The satellite images used in this study included 120 ASTER and 6 Landsat images which were provided by the United States Geological Survey (USGS). In addition, 22 Disaster Monitoring Constellation (DMC) images and 21 Landsat images were made available by the Joint Resaerch Centre (JRC) of the European Commission. The Landsat and DMC images were used to cover gaps that existed in ASTER images and also for areas where ASTER images could not be used due to high cloud cover, particularly areas along the coast. In addition the Landsat and DMC images were used as backup whenever the interpretation of the Aster images was leaving some space for ambiguity. This could be for example the seasonality (e.g. Aster image taken during dry season and Landsat during the crop season). The majority of the ASTER images used in this study were acquired during a time span ranging from December 2010 to April 2011.

Annex 2 lists the satellite images in terms of the satellite sensor type, scene number and date of acquisition, level of acquisition and purpose in the study.

The Aster datasets were delivered in single band GEOTIFF format. Landsat data were received in single band GEOTIFF format. All these images were received pre-processed for radiometric correction, atmospheric correction, geometric correction and noise-removal. The single band images were colour-composited and enhancement to improve their interpretability.

Colour compositing – This involved combining individual image bands to generate Colour Composites (CCs). False Colour Composites (FCCs) are created when the constituting bands are assigned the three primary (additive or true) colours (red, green and blue). The false colour composites were produced in ArcGIS software (Spatial Analyst extension) using bands 4, 3 and 2 for Landsat and 3, 2, and 1 for ASTER images.

Enhancement – The following enhancement procedures were applied:

Stretching – This was applied to the false colour composites to expand (proportionally reallocates) tonal distribution from lower to higher values present in the original image, to the full available grey scale display (usually subdivided into 255 grey tones). The contrast enhancement was characterized by improved appearance of different bodies with similar tones, emphasizing patterns and, to a lesser extent, roughness.

The high Resolution aerial photographs of the 2008 flight were also used, particularly around irrigated areas along the rivers. This complies with the definition of cultivable areas as land which has been cultivated at least once during the last 4 years (2008 – 2011) The study also made use of other spatial databases such as administrative boundaries, drainage, towns and settlements, and the road network.

2.3. Methods

Given the size of the area and the main objective of the study, a sampling technique had to be used. In fact, as compared to a wall to wall photo-interpretation of the whole area, sampling generally offers a significant reduction of the work load by obtaining at the same time higher statistical accuracy. A land cover map is only a second objective of the study and can be derived from the sampling points, although with a clearly lower resolution as compared with wall to wall interpretation.

Regularly spaced dot samples as in a classical dot grid method were used. This method for calculating areas has long been employed by foresters and other users of aerial photography. The Department of Resource Surveys and Remote, in Nairobi Kenya, for example, has for many decades successfully used the dot grid technique to generate district land cover/land use statistics (Ottichilo et al 1985). Using standard photo interpretation techniques discrete Land Use and Land Cover (LULC) classes that touch each dot in the grid are defined by the interpreter. The dots have virtually no area and the interpreter just checks what kind of land cover they fall onto. This approach minimizes the interpretation error as compared to points corresponding to an area since the point corresponds only to one land cover class and the interpreter has not to deal with percentages of land cover within the point area, or with borders between classes.

A 500 m distance between the dots was chosen in order to keep the photo-interpretation workload feasible without incurring into unacceptable sampling and interpretation errors. The 500 meter interval between the points over an area of 256,590 km^2 translated into a total number of 1033068 points being interpreted.

The software used for facilitating the interpretation work was the Rapid Land Cover Tool (RLCM) (http://lca.usgs.gov/lca/rlcm/index.php) which facilitates definition and generation of these dot grids, aids the selection of the blocks of the dots within common LULC classes and allows assigning the classification attribute to them.

Mapping land use and land cover (LULC) over large areas and through time has always presented major challenges. There are two contrasting approaches to LULC mapping: automated/semi-automated classifications and manual photo interpretation. The first approach is fast and efficient in classifying large areas but usually presents challenges in terms of accuracy, especially when comparing two or more time periods. The photo interpretation method produces good results for time series mapping but is very labour-intensive for large areas. The U.S. Geological Survey (USGS) developed the Rapid Land Cover Mapper (RLCM) to address these challenges. The desktop application is labelled RLCM, and a Web-based version is labelled wRLCM.
The desktop RLCM was created by scientists at the USGS Earth Resources Observation and Science (EROS) Center (http://eros.usgs.gov/). This tool was a simple and low-cost solution to facilitate the temporal LULC mapping project of West Africa for over 3 million sq km (http://lca.usgs.gov/lca/africalulc). It was developed using ESRI's ArcGIS / ArcMap environment and designed for use by moderately experienced Geographic Information System (GIS) users. The tool simplifies the LULC classification by facilitating and managing the classification attribution. By allowing users to work in the ArcMap environment, they can leverage all the resources of the GIS software to make the most concise photo interpretation.

To start the LULC interpretation process in RLCM, three preliminary tasks need to be completed: defining the geographic extent of the study area, defining the time periods to analyze, and acquiring the imagery of the selected time. Once these tasks are completed, the project can be initialized in the RLCM application. To initialize the application, these three preliminary tasks need to be configured into it. This is done by a series of dialog wizards that guide the user through the process. Once these steps are completed, the user can begin the photo interpretation process. Upon completion of the classification, the user has the option to export the dots as ESRI shape files for each time period or as raster datasets for further analysis.

Figure 2 below shows the dot grid as used in this study and overlaid to an ASTER satellite image.

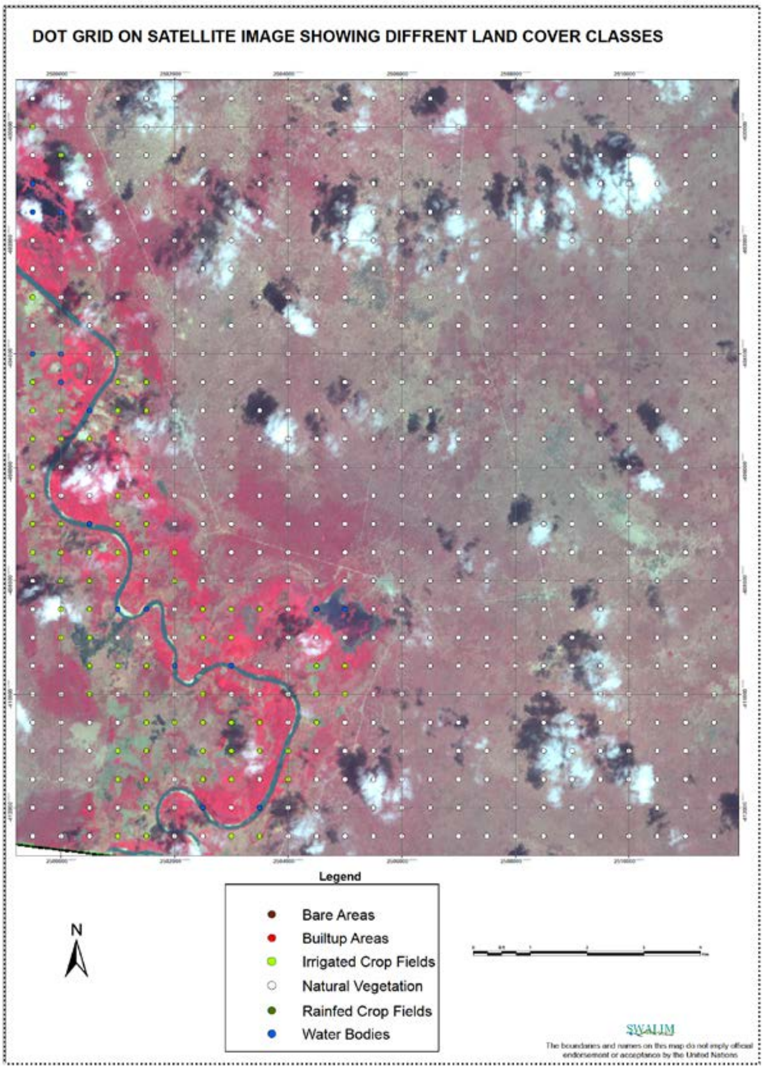


Figure 2: Dot Grid on the satellite image showing the different land cover types

The resulting attributed dots were exported as ESRI shape files for further analysis. MS-excel software was used to analyse the dots into the constituent land cover percentages and ultimate land cover areas in hectares and square kilometres. The point shape file of the entire study area was rasterized into a raster land cover map with the six classes. The Spatial Analyst software in ArcMap of ArcGIS was used to rasterize the point shape file. District summaries were then generated from the raster land cover map.

For this study, the following six land cover classes were used:

1. Rainfed crop fields
2. Irrigated crop fields
3. Natural vegetation
4. Built up area
5. Bare lands
6. Water bodies

By definition, rainfed crops are crops that entirely depend on rainfall to grow. Irrigated crops on the other hand are crops that also depend on supplementary water, besides rainfall, for their growth. The class natural vegetation refers to land cover that is covered by naturally growing vegetation. The vegetation considered here included all the three major life forms, trees, shrubs and herbaceous vegetation. The built up areas are with an artificial cover resulting from human activities. Areas that are primarily bare in this study are referred to as Bare areas. All water surfaces are in this activity referred to as Water bodies.

The classification of the land cover classes is based on the concepts outlined in the FAO Land Cover Classification System (LCCS) (Antonio Di Gregorio 2005).

The SWALIM land cover maps generated from the SWALIM aerial photographs of 2008 were used to demarcate the extent of the irrigated crop fields in the study area. Then all the points falling within the irrigated areas were selected and classified. Consequently, much time was saved in classifying the irrigated crop fields. Other image characteristics like shape, pattern and associated features like irrigation canals were also used to help identify the irrigated crop fields. All other land cover classes that were found to be homogenous over large areas were also classified by multiple selection of the dots falling on them.

The total sampling error approach is composed of the sampling and the interpretation error. The sampling error depends on the density of the sampling grid and the fragmentation of the observed land cover information. The accuracy of the sampling density was assessed by testing different sampling grid resolutions on a typical subset of the study area.

Sampling error and choice of dot interval in the dot grid

The choice of the interval between interpretation dots in the systematic sampling grid is driven by statistical and practical considerations. In theory the accuracy of the area estimates improves with a higher density of sampling, while the effort and cost for interpreting the larger number of dots will also increase. Therefore a compromise needs to be found in order to obtain good quality results with the lowest possible number of dots to be interpreted.

To have an idea of the impact of the sampling density on the quality of the final estimates Table 1 shows the changes in variance and coefficient of variation for a sampling density decreasing from 250m to 2000m in a 15 * 15 km example area.

According to the Bernoulli formula we compute the variance (p) as:
Variance (p) = p(1-p) /(n-1)
Where p is the probability of dots on cultivable area and n the total number of dots.

Table 1 shows a simulation where by increasing progressively the grid spacing by a factor 2 (from 250 up to 2000 m) the coefficient of variation also increases. For each increase of grid spacing we divided the number of interpreted dots by 4.

The 500 m grid spacing was considered a reasonable compromise of total number of dots to be interpreted by obtaining a good coefficient of variation value (5.1 %). With a 2000m spacing and hence an 8 times lower number of dots to be interpreted, the CV would have gone up to >20%. For the whole area the choice of the 500 m grid lead to the interpretation of 1033068 dots.

Table 1: Sampling density and quality of final estimate

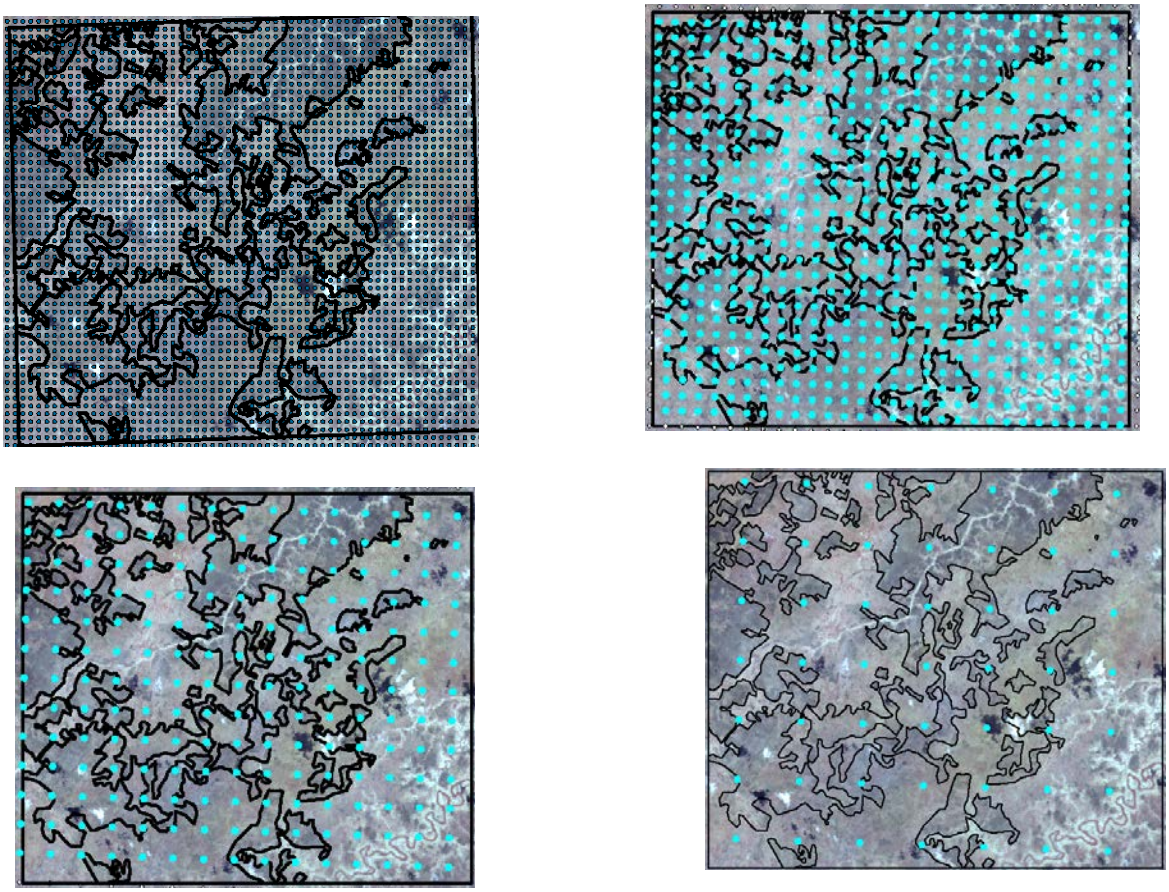
Grid spacing	**Total nr. of dots**	**Dots on cultivable area (simulated)**	**Dots on cultivable area in % (p)**	**Estimated Cultivable area in ha**	**Variance (p)**	**SD (p)**	**SD ha**	**Variation Coefficient**
250	3,117	*1,023*	32.8%	7,385	0.000071	0.84%	189	**2.6%**
500	779	256	32.8%	7,385	0.000283	1.68%	379	**5.1%**
1000	195	64	32.8%	7,385	0.001138	3.37%	759	**10.3%**
2000	49	16	32.8%	7,385	0.004622	6.80%	1,530	**20.7%**

In order to provide also a visual example of the statistics in Table 1, and how the different sampling densities represent the cultivable land use class, the mentioned grid spacing were overlaid on an image area measuring 15*15 km as seen in Figure 3. For purely visual purposes, polygons were manually delineated for all the observed cultivable areas on the satellite image. This is only to give an idea of how the sample grid dots represent the cultivable area.

Figure 3: Dot grid and land cover computations to determine choice of dots interval

(a) 250 dot interval grid

(b) 500 dot interval grid



(a) 1000 meter dot interval

(d) 2000 m dot interval

Finally it is interesting to observe (table 2) that even for a small area like 15*15 km there is a relatively good correspondence between the theoretical number of dots for each grid density as used in Table 1 and the dots falling effectively on the photointerpreted area in the example of Figure 3.

The deviations of the total number of dots in Table 2 are influenced by the way the 15*15 km is cutting the grid, i.e. the 15 km grid is not matching exactly with the first row and column of dots. This is also the reason why the number of total dots for the 250 m spacing in Table 2 is not a multiple of 250.

Table2: Total number of dots by spacing and dots on cultivable area

Grid spacing	Total nr. of dots	Dots on cultivable area (simulated)
250	3,117	*1,023*
500	779	256
1000	187	49
2000	49	16

Interpretation error

The interpretation error depends mainly on the experience and ability of the each photo-interpreter and therefore measures the subjectivity of the interpretation. However, even for experienced interpreters this error does also depend on other factors such as the quality of the images, the complexity of the classification categories and the time available for interpretation. In this study 3 interpreters with relevant experience in the region and in the use of RLCM were used and the interpretation error was assessed by running the interpretation independently with the 3 interpreters for one district (Afgoye district) of the study area (1.54% of the total area). The district is representative for the total area because all main land cover classes are found there with a reasonably homogeneous distribution within the district. The only land cover class not represented, but also not really relevant for the assessment of the cultivable area is the water bodies.

As can be seen in Table 3, the standard deviation and coefficient of variation is high for the rainfed and the irrigated crop fields and very low for natural vegetation, bare land and built up areas. This means that the distinction between the sum of rainfed and irrigated cultivable land and other land use categories is good, while the interpretation between rainfed and irrigated areas is highly variable from interpreter to interpreter. This is also confirmed by the coefficient of variation for the sum of rainfed and irrigated (2%), which is again very low.

These considerations do only give a quick overview of differences in the interpretation which can be due to subjectivity. However, the standard deviation and coefficient of variation for only 3 groups of observations are not highly representative. More detailed information on the interpretation error could be obtained by looking at the agreement among the 3 interpreters at single point level.

Table 3: standard deviation and coefficient of variation

Points by interpreter	**Int1**	**Int2**	**Int3**	**mean**	**SD est**	**V coef**
Land Cover Class						
Rainfed Crop Fields	6134	4856	5749	5579.7	983.42	**17.6%**
Irrigated Crop Fields	3254	4539	3869	3887.3	964.04	**24.8%**
Total cultivable area	*9388*	*9395*	*9618*	9467.0	196.22	**2.1%**
Natural Vegetation	6028	6054	5845	5975.7	170.86	**2.9%**
Bare Areas	192	185	178	185.0	10.50	**5.7%**
Builtup Areas	149	154	149	150.7	4.33	**2.9%**
Waterbodies	0	0	0	0.0	0.00	**_**
Total non cultivable	6369	6393	6172	6311.3	181.89	**2.9%**
Total	15788	15788	15788	15778		

3. RESULTS, DISCUSSION AND CONCLUSION

3.1. Results

The results obtained from the study are presented in form of tables, pie-charts and a raster maps showing the distribution of land cover over the study area and for single districts (Annex 1). The raster land cover map was derived from the shape file of the interpreted dots. Figure 4 and Table 4 are summaries of the results obtained for the whole study area. Table 5 gives the results for the entire study area from both the regional and district perspectives while Figure 5 is the land cover map of the study area. Table 6 summarises the results from the regional perspective. The results show that agriculture occupies just about 9% (23,863 km2) of land in the study area while natural vegetation covers about 90% (or 229,648 km2) of the study area. The remaining 1% (3260 km2) comprises the other cover types including bare areas, built-up areas and water bodies. Of the agricultural land, rain-fed agriculture occupies approximately 7% (or 17,961 km^2) while irrigated agriculture takes up about 2% (or 5,132 km^2).

Table 4: Overall land cover in the study area

Land Cover Type	No. of points	Percent Cover	Area (Ha)	Area (km^2)
Built-up Areas	704	0.1	17831	178
Water Bodies	995	0.1	26287	263
Bare Areas	11167	1.1	281721	2,817
Irrigated Crop Fields	23486	2.3	591325	5,913
Rainfed Crop Fields	72171	7.1	1814747	18,147
Natural Vegetation	924545	89.3	22928645	229,286
Total	1033068	**100**	25660556	256,606

Figure 4: Land cover in the study area

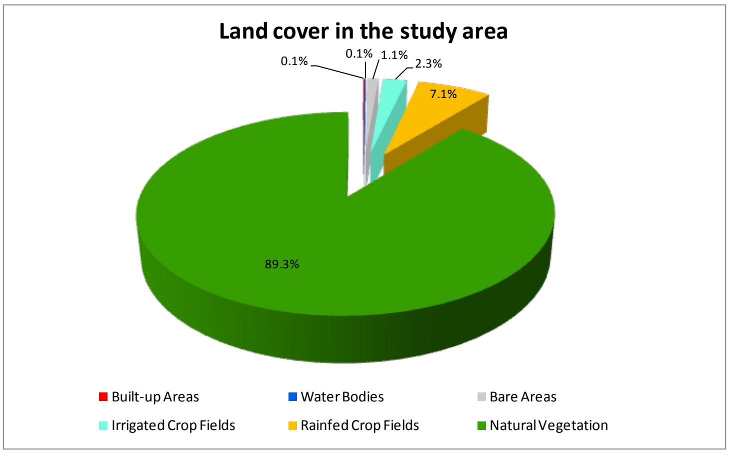


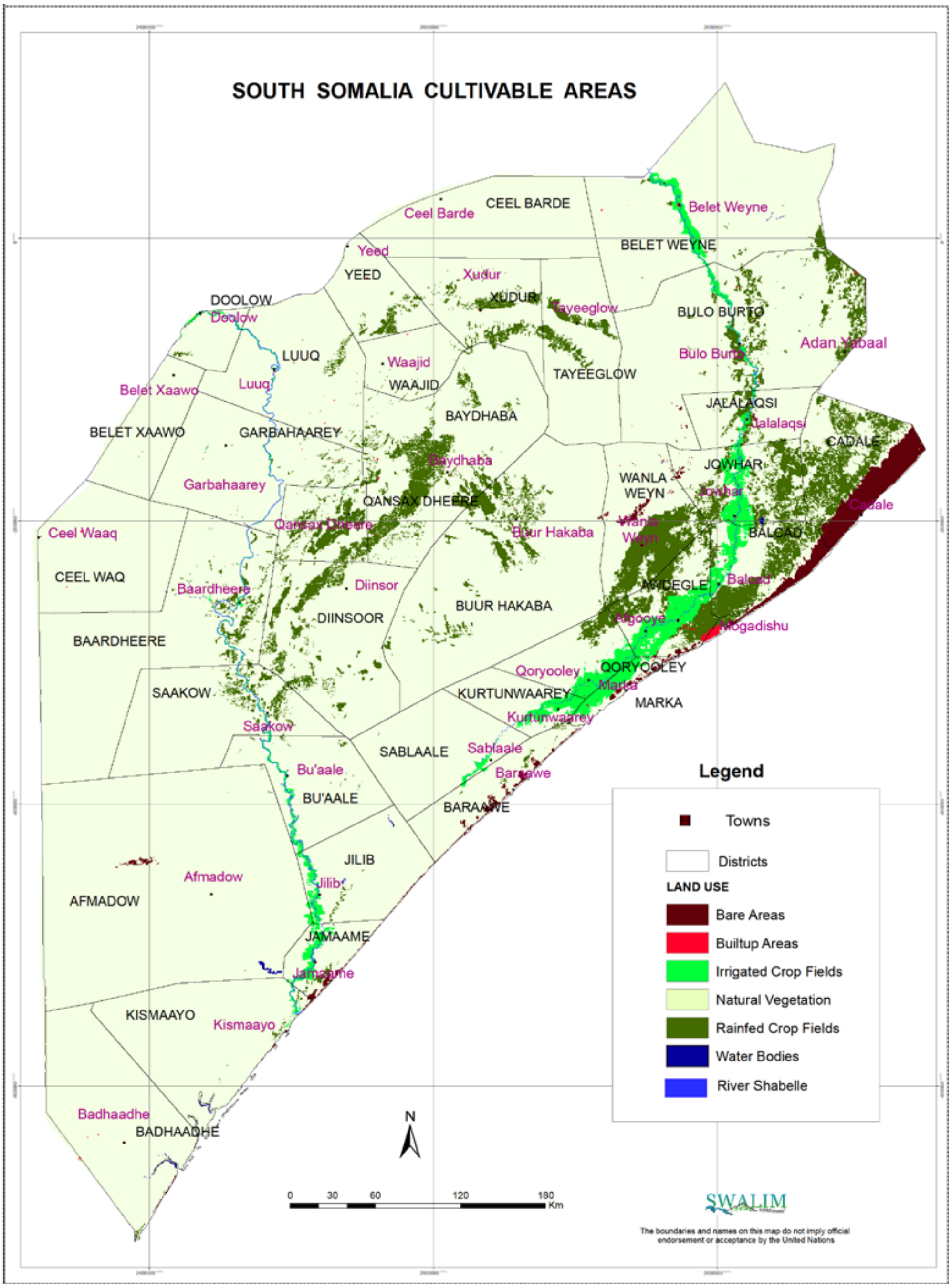
Table 5: Summary of the results from the study area

CULTIVABLE AREAS IN HECTARES							
Region	District	**Irrigated Crop Fields**	**Rainfed Crop Fields**	**Natural Vegetation**	**Water Bodies**	**Built-up Areas**	**Bare Areas**
Lower Juba	Afmadow	4963	0	2671570	5743	82	5907
	Badhaadhe	0	1488	959855	1538	378	1639
	Jamaame	31616	6252	167727	683	75	8783
	Kismayu	5318	3277	914046	1209	0	0
Gedo	Baardheere	10503	45671	1476175	3183	125	0
	Belet Xaawo	0	0	388965	50	0	0
	Ceel Waaq	0	0	784681	0	403	0
	Doolow	4653	0	157281	1241	26	0
	Garbahaarey	3071	10135	817183	2377	225	0
	Luuq	5241	10909	808395	2156	601	150
Bay	Baydhaba	0	218524	1071506	0	499	299
	Buur Hakaba	0	123534	1677682	0	0	659
	Diinsor	0	99894	873734	0	248	0
	Qansax Dheere	75	94268	232489	50	0	0
Lower Shabelle	Baraawe	1453	4794	302094	0	102	20578
	Afgooye	113652	121590	151587	0	3856	4632
	Kurtunwaarey	39114	2048	213084	0	224	0
	Marka	52060	704	42410	0	260	11085
	Mogadishu	0	9317	3388	0	6635	4291
	Qoryooley	60431	28779	231332	0	599	0
	Sablaale	8428	50	590737	75	0	0
	Wanla Weyn	0	179613	378957	624	624	11490
	Belet Weyne	46357	12222	1419522	426	751	275
Hiran	Bulo Burto	21065	147708	1446924	149	749	1324
	Jalalaqsi	9840	26350	273598	124	124	774
	Balcad	50192	151157	178551	227	278	42542
Middle Shabelle	Cadale	0	197062	224363	0	0	161265
	Jowhar	73028	136913	249217	1424	374	3448
	Ceel Barde	0	0	768302	0	47	0
Bakool	Tayeeglow	0	50869	608336	0	0	0
	Waajid	0	2599	277716	0	50	0
	Xudur	0	59589	482922	0	346	74
	Yeed	0	22483	308291	0	0	227
	Bu'aale	17841	2552	526393	2327	0	375
Middle Juba	Jilib	26114	3408	491761	1629	125	1904
	Saakow	6310	40988	757871	1052	25	0
Total		**591325**	**1814747**	**22928645**	**26287**	**17831**	**281721**
%		**2.3**	**7.1**	**89.4**	**0.1**	**0.1**	**1.1**

Table 6: Land cover types in different regions within the study area (given in hectares)

Region	**Irrigated Crop Fields**	**Rainfed Crop Fields**	**Natural Vegetation**	**Water Bodies**	**Built-up Areas**	**Bare Areas**
Hiran	81097	325215	1899073	500	1151	44640
Bakool	17841	138092	2203658	2327	396	676
Gedo	23468	66715	4432680	9007	1380	150
Bay	75	536220	3855411	50	747	958
Middle Shabelle	73028	333975	1241882	1424	421	164713
Lower Shabelle	321495	359117	3333111	1125	13051	52351
Middle Juba	32424	44396	1249632	2681	150	1904
Lower Juba	41897	11017	4713198	9173	535	16329
Total	591325	1814747	22928645	26287	17831	281721

Figure 5: Land cover map of the study area



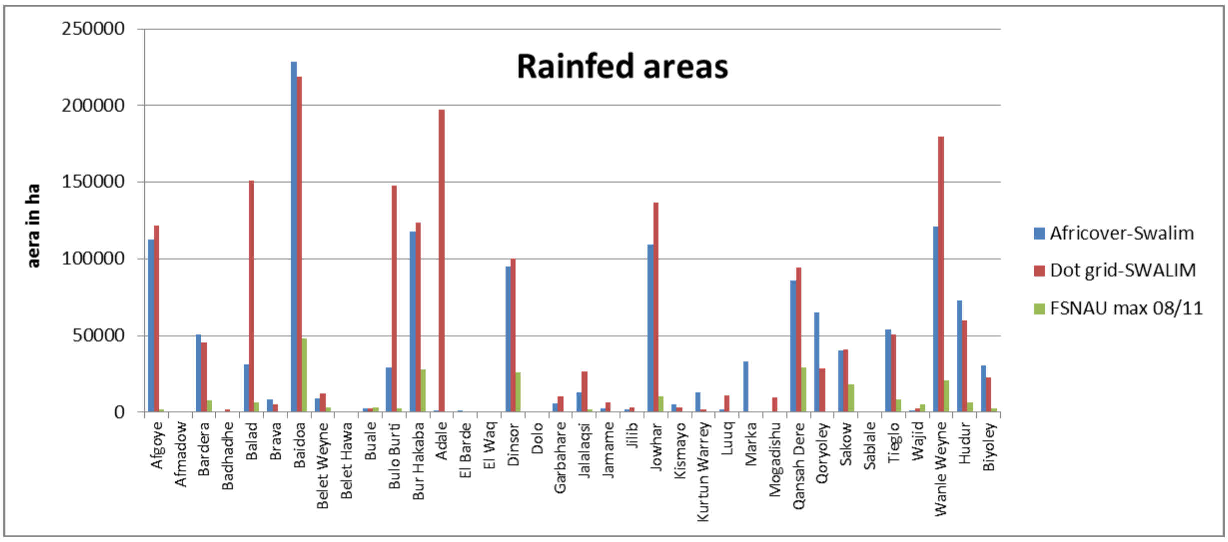
Comparison between dot-grid cultivable areas and FSNAU crop area estimates

FSNAU has been estimating crop areas for each crop season at district level for Somalia since 1995. The method is based on the analysis of proxy indicators from different sources (mostly interviews) which are used to estimate possible deviations from the baseline area by livelihood zone and by district according to seasonal variability. These area estimates are methodologically very different from the remote sensing based cultivable areas such as those that can be derived from the Africover and SWALIM land cover data and from the dot-grid method described here. In fact, while the cultivable area estimates keep memory of all the fields that have been cultivated in a 4 years' time period, the FSNAU cultivated areas only estimate what has been effectively cropped in a given season. On top of this, the cultivable area estimated by SWALIM includes fallow land, while the FSNAU estimates don't. According to recent VHR satellite image analysis for selected areas in Lower Shabelle, the average fallow area in the riverine zones of Lower Shabelle is at least 50%, while in marginal rainfed areas the fallow fields are expected to be even more than 50%. For these reasons it is not surprising that the cultivable areas estimated by this analysis are significantly higher than those estimated by FSNAU and can be considered as potentially cultivable area if all fields that have been planted in the last 4 years were planted at the same time. For rainfed areas the SWALIM cultivable area (1,814,747 ha) is >7 times higher than the FSNAU maximum of the last 4 Gu seasons (231,365 ha) while for irrigated areas the difference is of a factor 4 (591,325 ha versus 135,855 ha) . A possible underestimation of the FSNAU estimates can also not be excluded since it is not possible to get a quantitative error associated to those estimates.

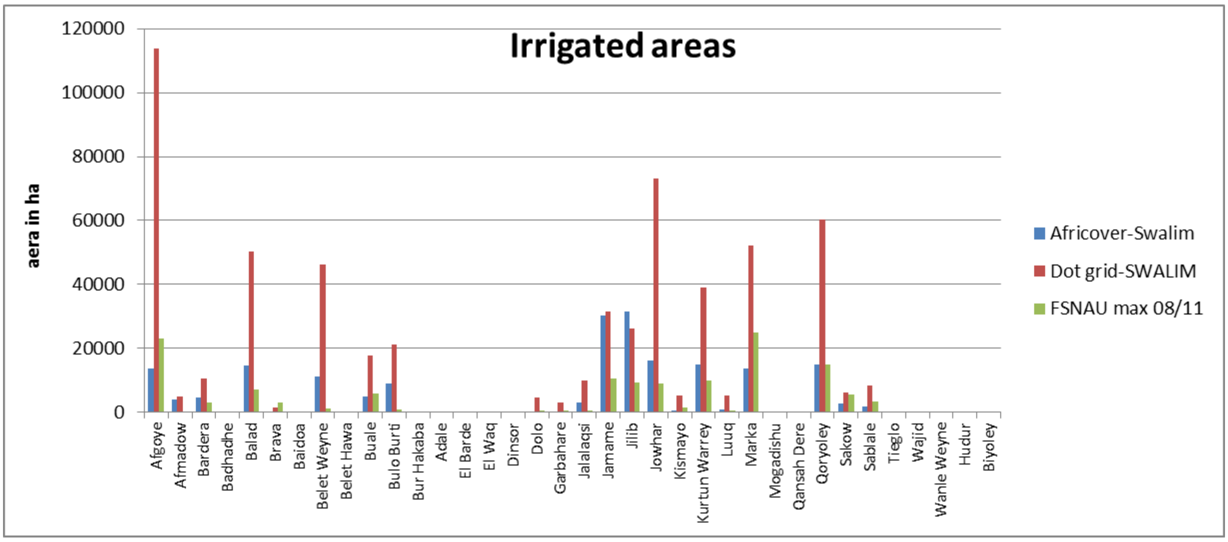
The graphs below show that there is a very good agreement between the dot grid estimates and the Africover-SWALIM land cover areas of the early 2000's, while the FSNAU planted areas are significantly lower. In some districts like Bulo Burti (Hiran) and Adale and Balad (Middle Shabelle) the areas estimated by the current study are significantly higher than the Aricover-SWALIM data, which indicates a significant increase in rainfed agricultural area over the last 10 years.

Irrigated cultivable areas of the current study are generally much higher than both the Africover data and the FSNAU data, indicating that they were probably seriously underestimated by Africover and FSNAU.

As a conclusion of this comparison, it can be said that direct observation by satellite images gives an accurate estimate of the agricultural area, but these estimates represent the so called cultivable area (including fallow fields, see definition in the introduction of this study) and not what has effectively been planted during a single season.



Rainfed areas
aera in ha
250000
200000
150000
100000
50000
0
Afgoye
Afmadow
Bardera
Badhadhe
Balad
Brava
Baidoa
Belet Weyne
Belet Hawa
Buale
Bulo Burti
Bur Hakaba
Adale
El Barde
El Waq
Dinsor
Dolo
Garbahare
Jalalaqsi
Jamame
Jilib
Jowhar
Kismayo
Kurtun Warrey
Luuq
Marka
Mogadishu
Qansah Dere
Qoryoley
Sakow
Sablale
Tieglo
Wajid
Wanle Weyne
Hudur
Biyoley
Africover-Swalim
Dot grid-SWALIM
FSNAU max 08/11



Irrigated areas
aera in ha
120000
100000
80000
60000
40000
20000
0
Afgoye
Afmadow
Bardera
Badhadhe
Balad
Brava
Baidoa
Belet Weyne
Belet Hawa
Buale
Bulo Burti
Bur Hakaba
Adale
El Barde
El Waq
Dinsor
Dolo
Garbahare
Jalalaqsi
Jamame
Jilib
Jowhar
Kismayo
Kurtun Warrey
Luuq
Marka
Mogadishu
Qansah Dere
Qoryoley
Sakow
Sablale
Tieglo
Wajid
Wanle Weyne
Hudur
Biyoley
Africover-Swalim
Dot grid-SWALIM
FSNAU max 08/11

3.2. Discussions and conclusions

The medium resolution satellite imagery can be rapidly used to gather fairly accurate land cover information covering large areas including inaccessible ones. The spatial-temporal properties of these satellite data sources make it possible to monitor land cover dynamics over time. On the other hand, the Dot Grid analysis technique can be used to generate statistics rapidly and with a high level of statistical accuracy. Superimposing the dot grid over the same area or subsets over different periods will help in land cover change monitoring initiatives. The comparison with Africover data in the previous paragraph also confirms that the dot grid methods provides results in terms of land cover statistics which are very close to those of Africover, but in a much more rapid way than by doing land cover interpretation for the full area such as done by the Africover project.

The information coming out of this exercise regarding cultivable land and cropping patterns will support decision making on programme design for different regions/districts, particularly with regard to the factors limiting agricultural production such as land, labour, water, capital, farmers and market organization). This information is also crucial for planning agricultural input distribution, cash for work and other intervention for both emergency and regular programmes. Additionally, the information about cultivable land can also be used as baseline in the crop assessment at the end of each season.

This study also forms the basis for a successive, more accurate and more detailed analysis which could include sampling approaches and field validation (through FAO emergency staff and FSNAU monitors) in order to establish the potentially cultivable land and estimate production for the different cropping systems. Subsequently, the successive study could receive input from FSNAU crop assessments conducted at village (farmer) and district (key informants) levels, given that FSNAU assessment collects data on area planted or harvested as well as yield and production. The detailed study could consequently be complemented by the use of more detailed Remote Sensing products like the high resolution satellite images (GeoEye and World View satellite images). In the case of improved availability of high resolution satellite imagery for a single crop season, the same method could be used to estimate actual seasonal crop area with a high level of accuracy. In this case only a part of the whole area would be needed to be covered with very high resolution images in a sampling approach.

This study therefore, recommends the successive and regular use of high resolution satellite data sources to ultimately help generate more detailed cultivable area data.

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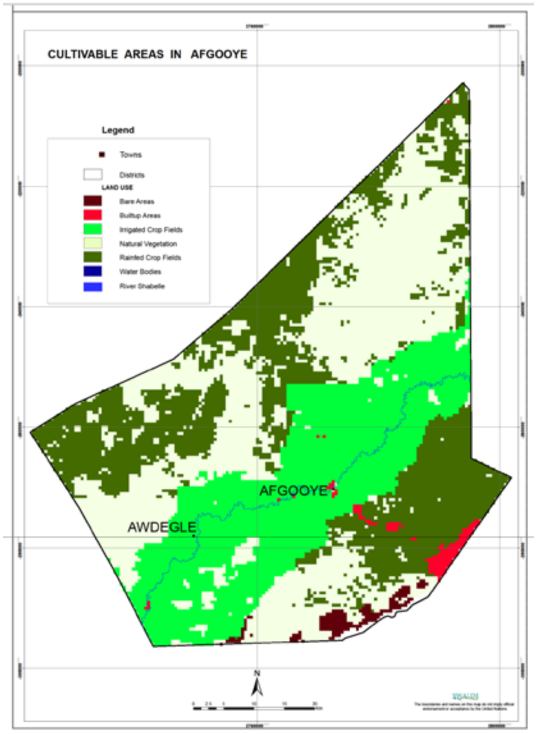
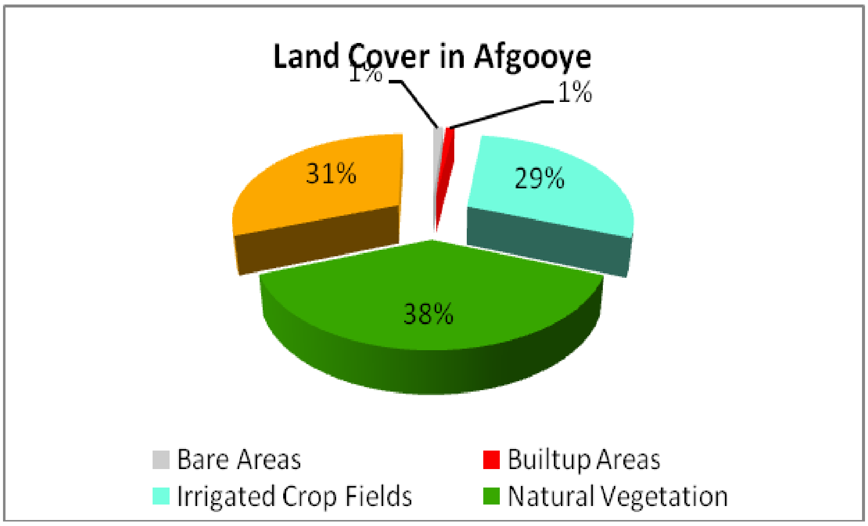
ANNEXES

ANNEX 1

Results by District

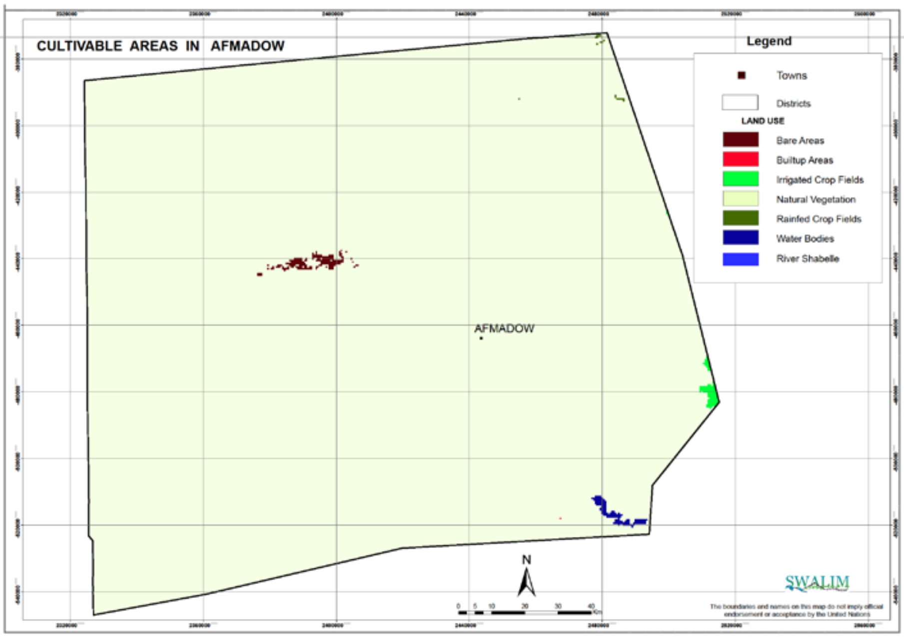
1. AFGOOYE DISTRICT



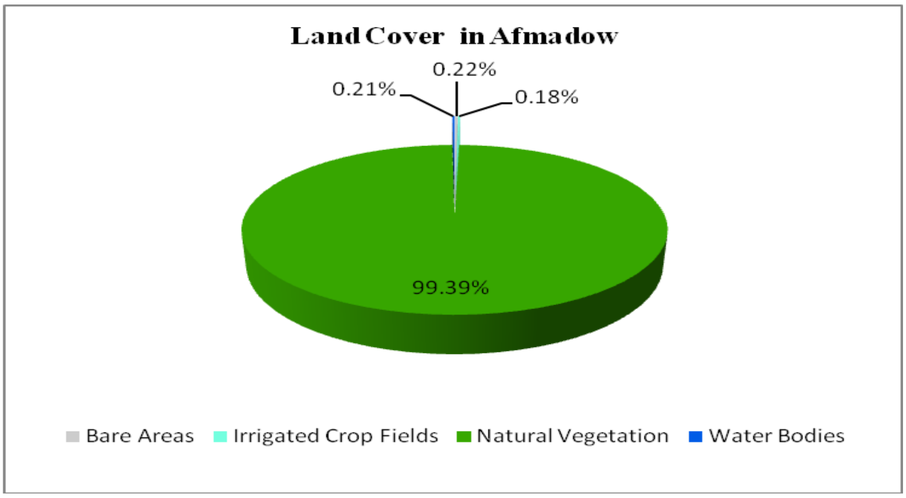


2. AFMADOW DISTRICT

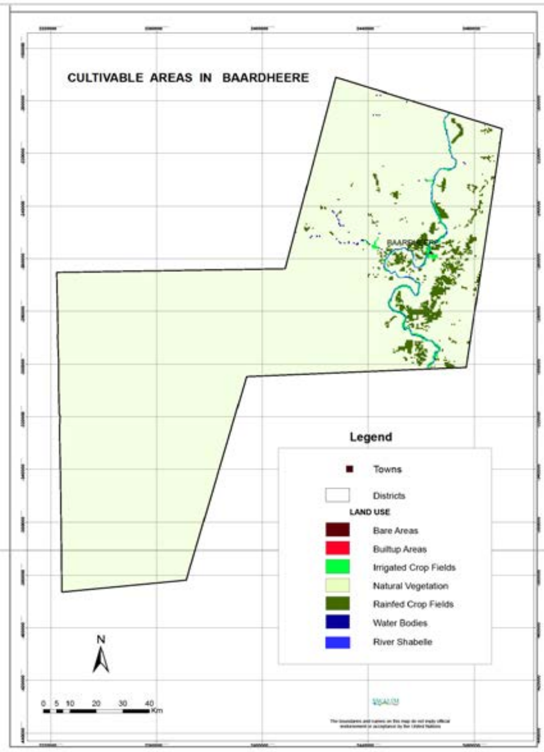
Land Cover in Afgooye District	Number of Dots	Percentage (%)	Area (Ha)	Area (Sq.km)
Bare Areas	185	1.2	4632	46
Builtup Areas	154	1.0	3856	39
Irrigated Crop Fields	4539	28.7	113652	1137
Natural Vegetation	6054	38.3	151587	1516
Rainfed Crop Fields	4856	30.8	121590	1216
Water Bodies	0	0.0	0	0
Total	**15788**	**100.0**	**395317**	**3953**



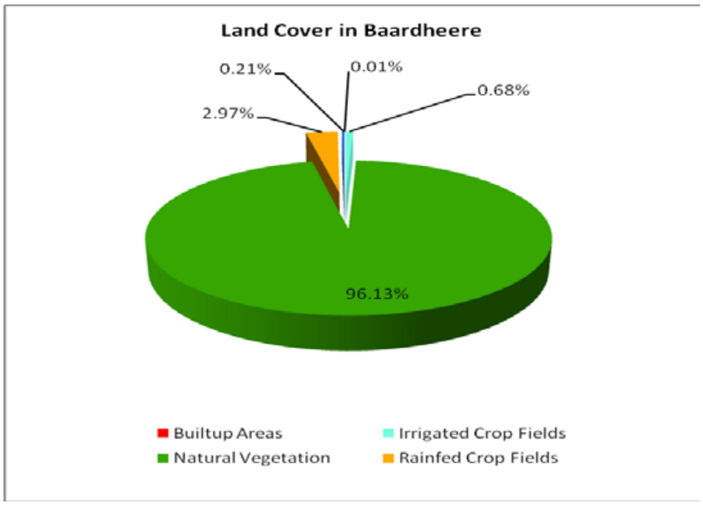
Land Cover Types Afmadow District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq. Km)
Bare Areas	144	0.22	5906.92	59
Builtup Areas	2	0.00	82.04	0.82
Irrigated Crop Fields	121	0.18	4963.46	49.6
Natural Vegetation	65128	99.38	2671569.74	26716
Rainfed Crop Fields	0	0.00	0.00	0
Water Bodies	140	0.21	5742.84	57
Total	**65535**	**100.00**	**2688265.00**	**268826**



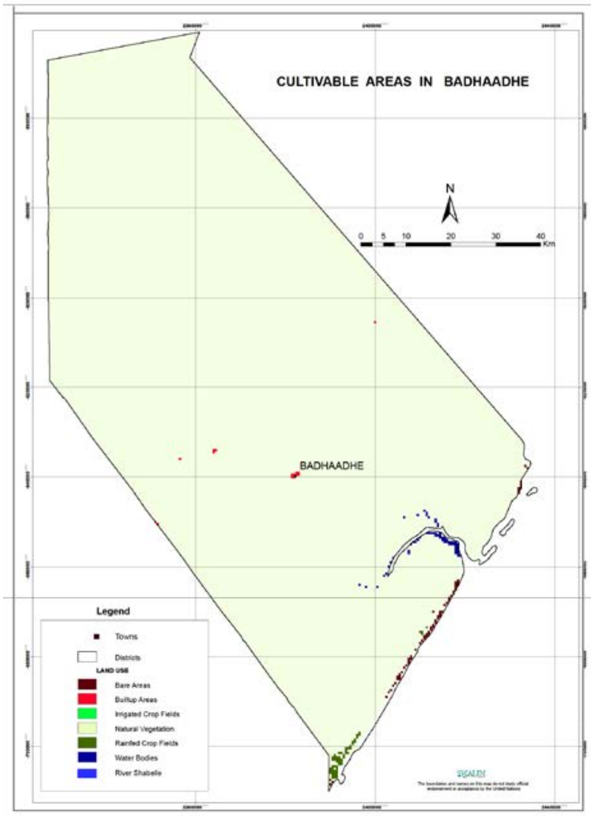
3. BAARDHEERE DISTRICT



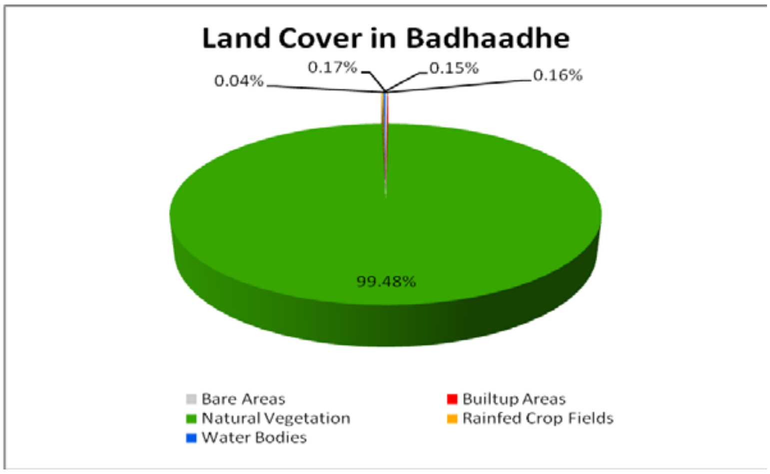
Land Cover Type Baardheere District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq. km)
Builtup Areas	5	0.01	125.33	1.25
Irrigated Crop Fields	419	0.68	10502.75	105
Natural Vegetation	58891	96.13	1476174.86	14762
Rainfed Crop Fields	1822	2.97	45670.66	457
Water Bodies	127	0.21	3183.41	32
Total	**61264**	**100.00**	**1535657.00**	**15357.25**



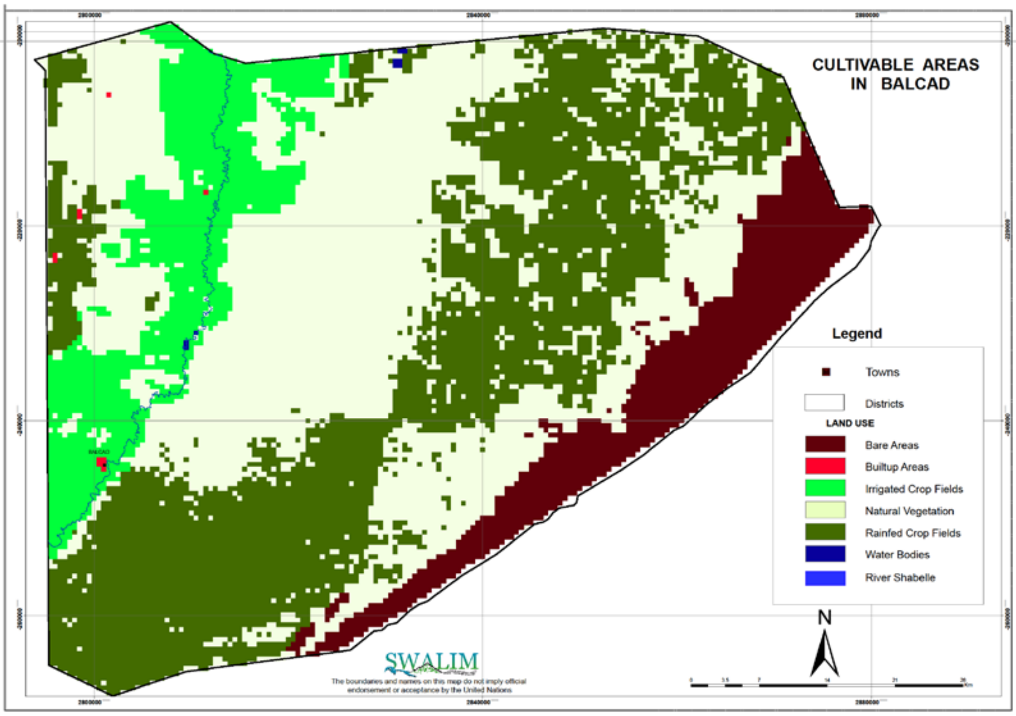
4. BADHAADHE DISTRICT



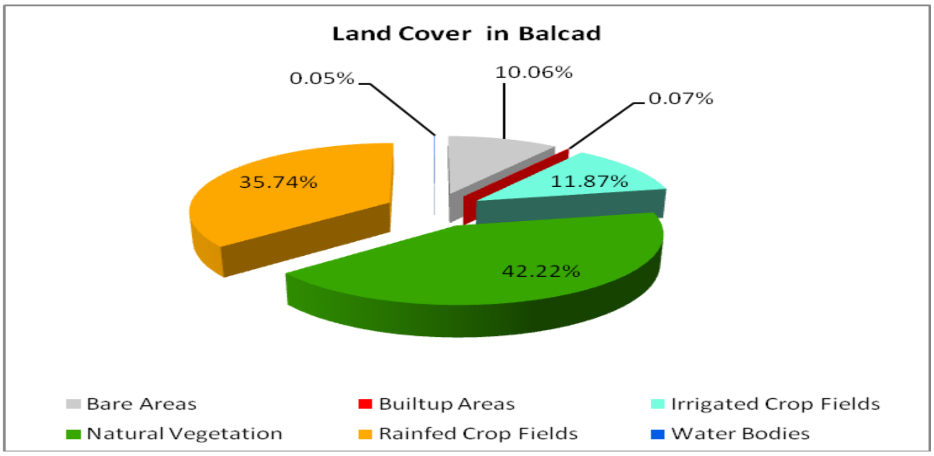
Land Cover Types Badhaadhe District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	65	0.17	1639.053	16.4
Builtup Areas	15	0.04	378.243	3.78
Natural Vegetation	38065	99.48	959854.8	9598.55
Rainfed Crop Fields	59	0.15	1487.756	14.9
Water Bodies	61	0.16	1538.188	15.38
Total	**38265**	**100.00**	**964,898**	**9649**



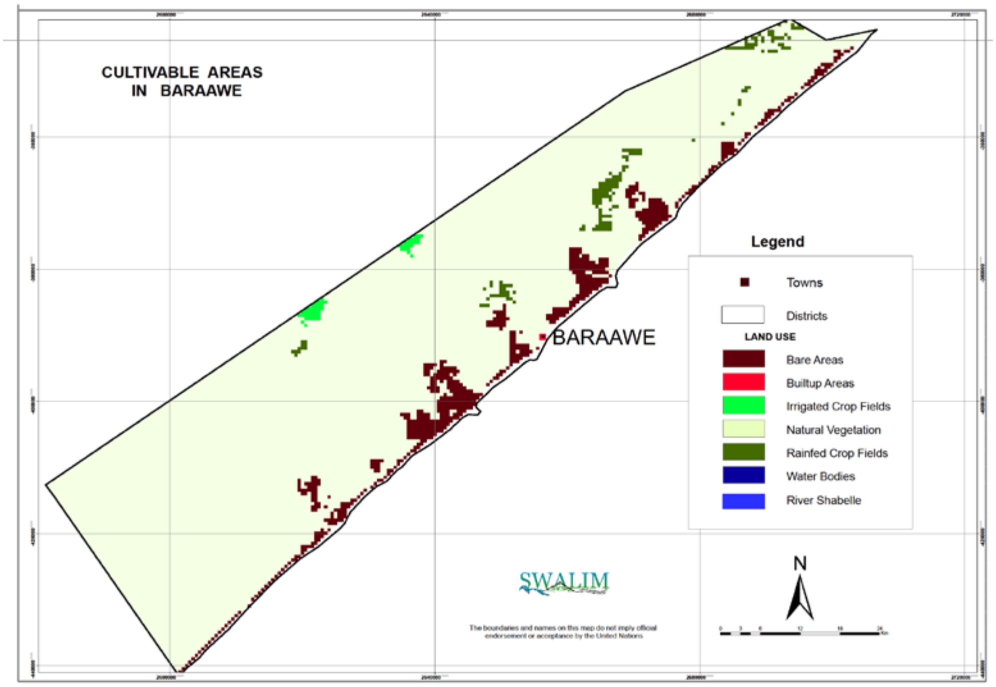
5. BALCAD DISTRICT



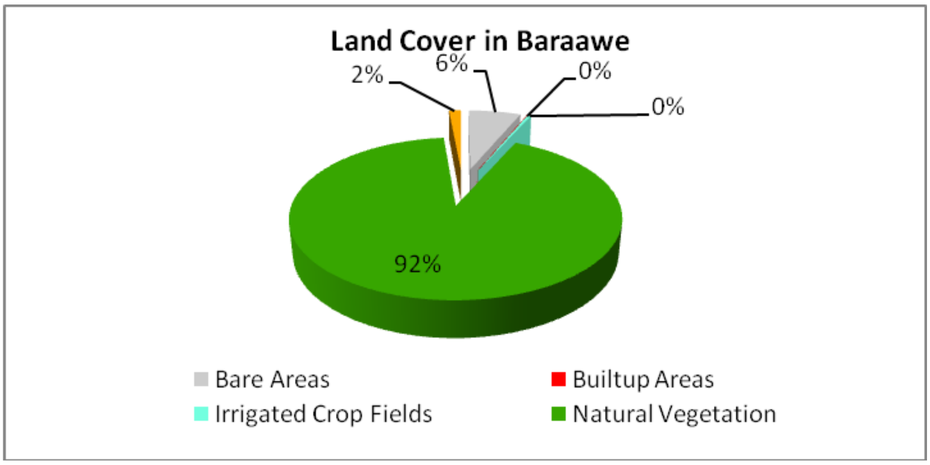
Land Cover Type Balcad District	No. of Dot	Percentage (%)	Area (Ha)	Area (sq. km)
Bare Areas	1685	10.06	42542.13	425
Builtup Areas	11	0.07	277.7231	3
Irrigated Crop Fields	1988	11.87	50192.13	501
Natural Vegetation	7072	42.22	178550.7	1786
Rainfed Crop Fields	5987	35.74	151157.1	1512
Water Bodies	9	0.05	227.228	2
Total	**16752**	**100.00**	**422,947**	**4229**



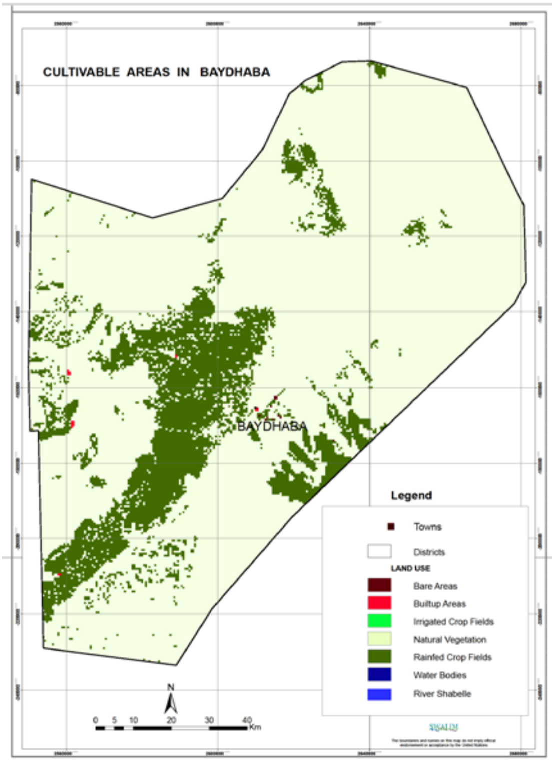
6. BARAAWE DISTRICT



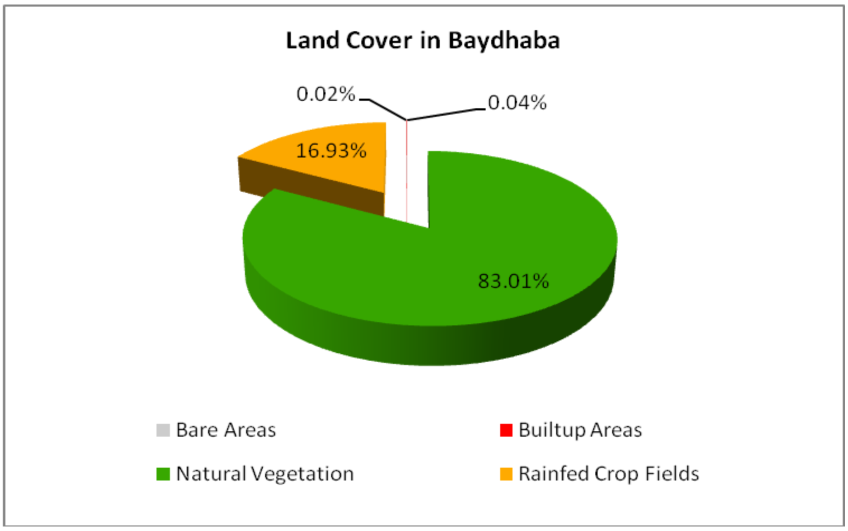
Land Cover Type Baraawe District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	807	6.25	20578.22	206
Builtup Areas	4	0.03	101.9986	1
Irrigated Crop Fields	57	0.44	1453.48	14
Natural Vegetation	11847	91.82	302094.4	3021
Rainfed Crop Fields	188	1.46	4793.934	48
Total	**12903**	**100.00**	**329,022**	**3290**



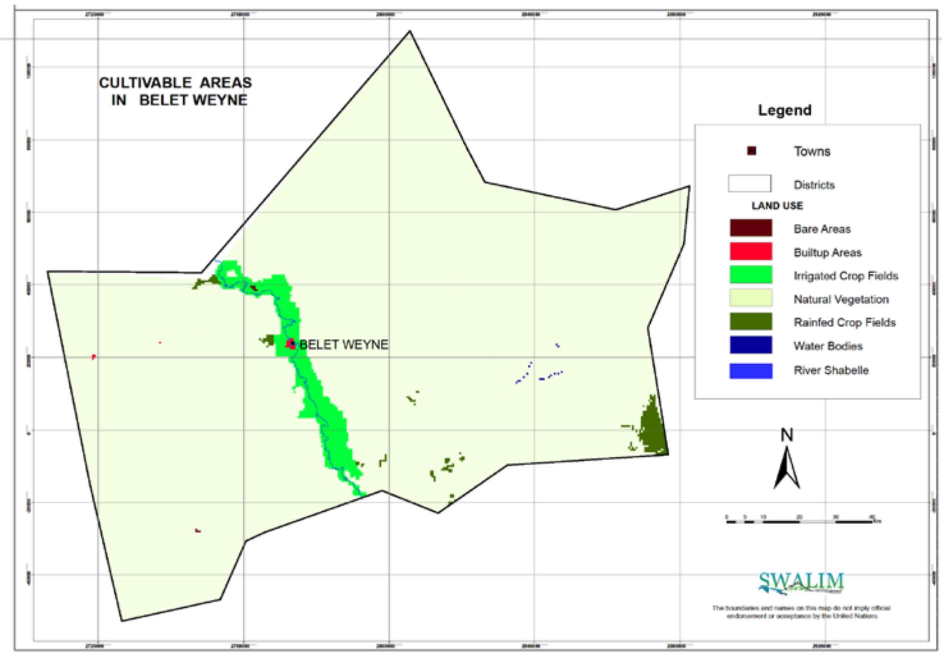
7. BAYDHABA DISTRICT



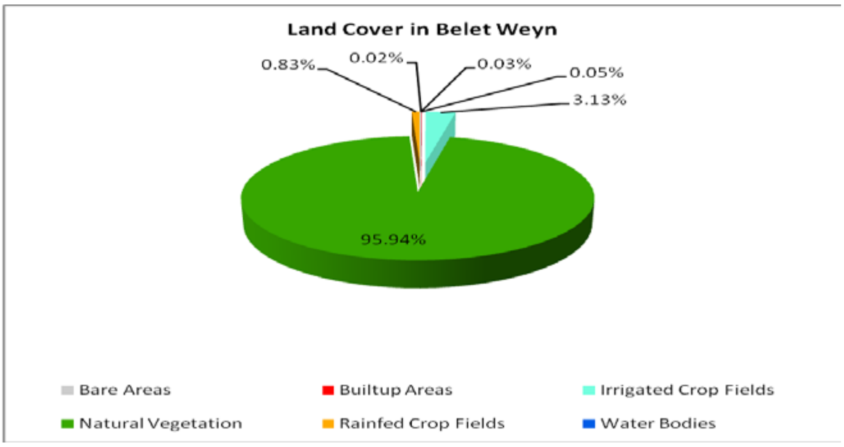
Land Cover Types Baydhaba District	No. of Dots	Percentage (%)	Area (Ha)	Area (sqkm)
Bare Areas	12	0.02	299.8968	3
Builtup Areas	20	0.04	499.8281	5
Natural Vegetation	42875	83.01	1071506	10715
Rainfed Crop Fields	8744	16.93	218524.8	2185
Total	**51651**	**100.00**	**1,290,831**	**12908**



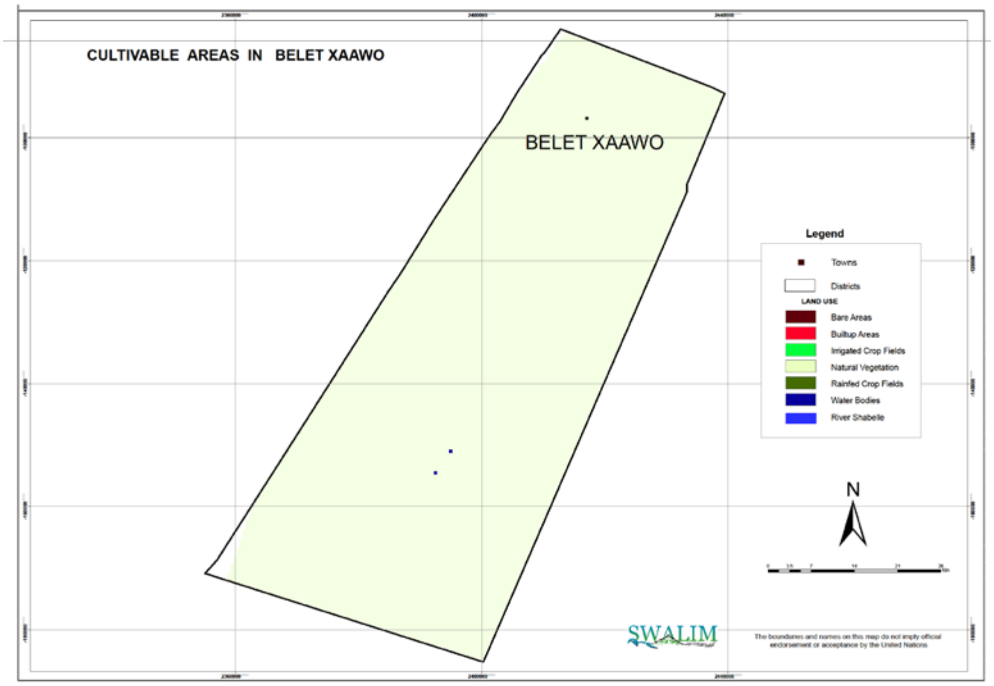
8. BELET_WEYNE DISTRICT



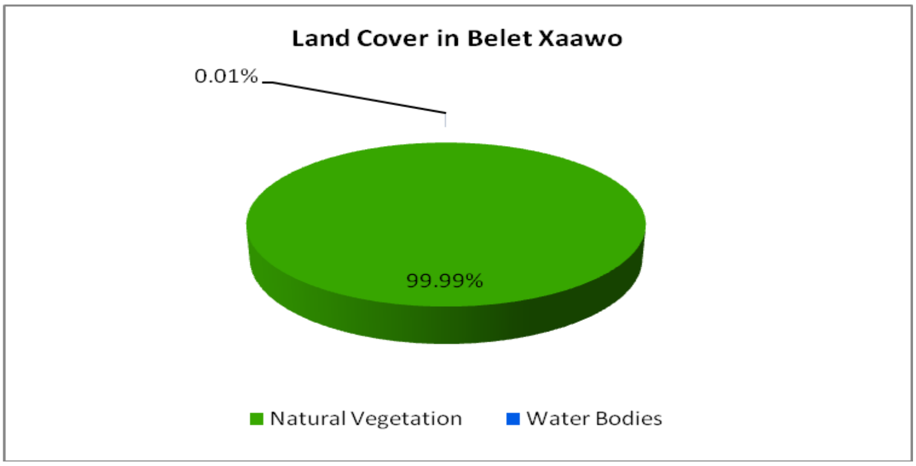
Land Cover Type Belet Weyn District	**No. of Dots**	**Percentage (%)**	**Area (Ha)**	**Area (sq.km)**
Bare Areas	11	0.02	275.4895	2.75
Builtup Areas	30	0.05	751.335	7.5
Irrigated Crop Fields	1851	3.13	46357.37	463.57
Natural Vegetation	56680	95.94	1419522	14195
Rainfed Crop Fields	488	0.83	12221.72	122
Water Bodies	17	0.03	425.7565	4.26
Total	**59077**	**100.00**	**1,479,554**	**14795.08**



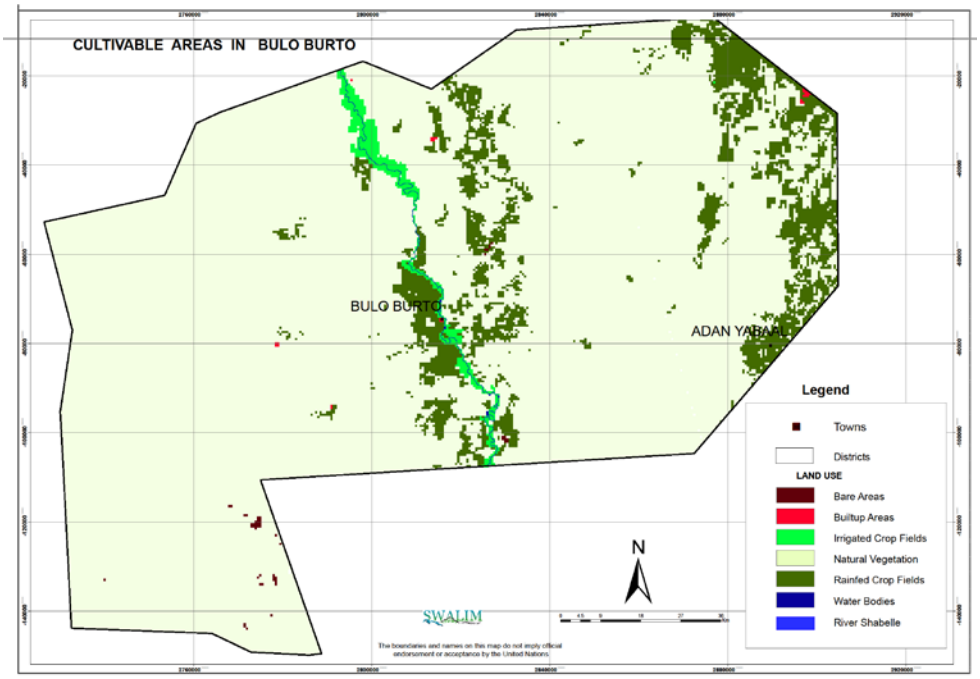
9. BELET_XAAWO DISTRICT



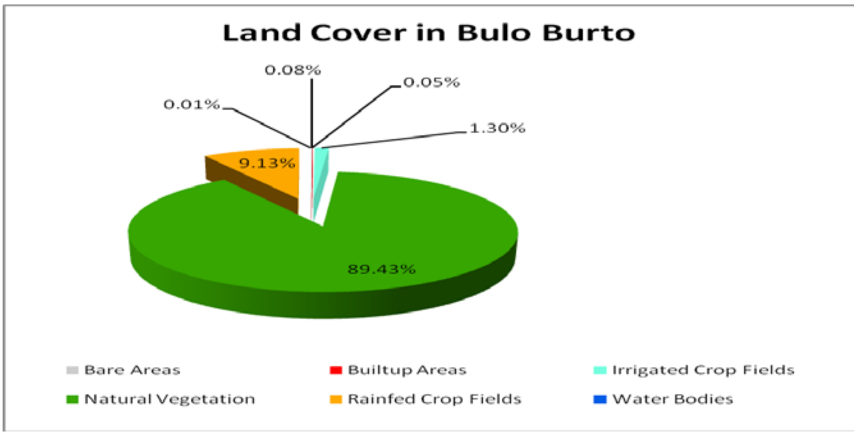
Land Cover Type Belet_Xaawo District	**No. of Dots**	**Percentage (%)**	**Area (Ha)**	**Area (sq.km)**
Natural Vegetation	15438	99.99	388965.6	3889.66
Water Bodies	2	0.01	50.39067	0.504
Total	**15440**	**100.00**	**389,016**	**3890.164**



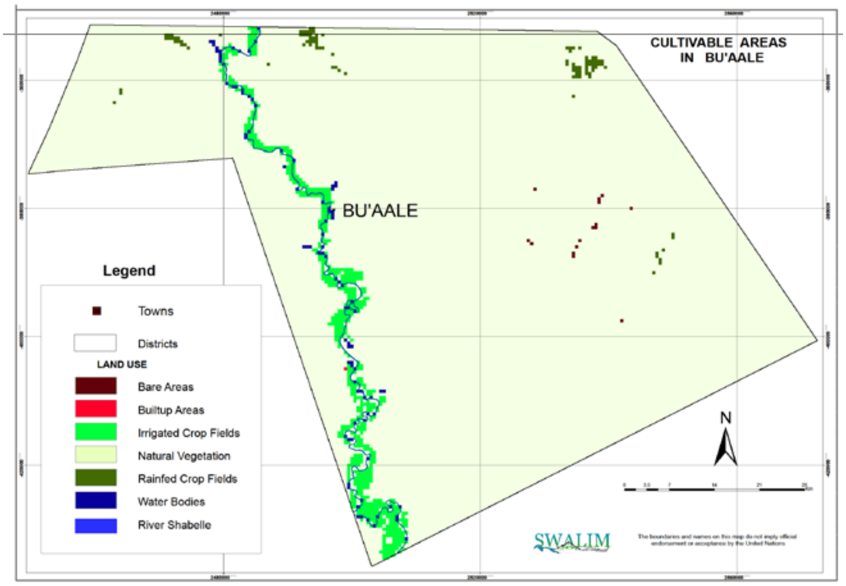
10. BULO BURTO DISTRICT



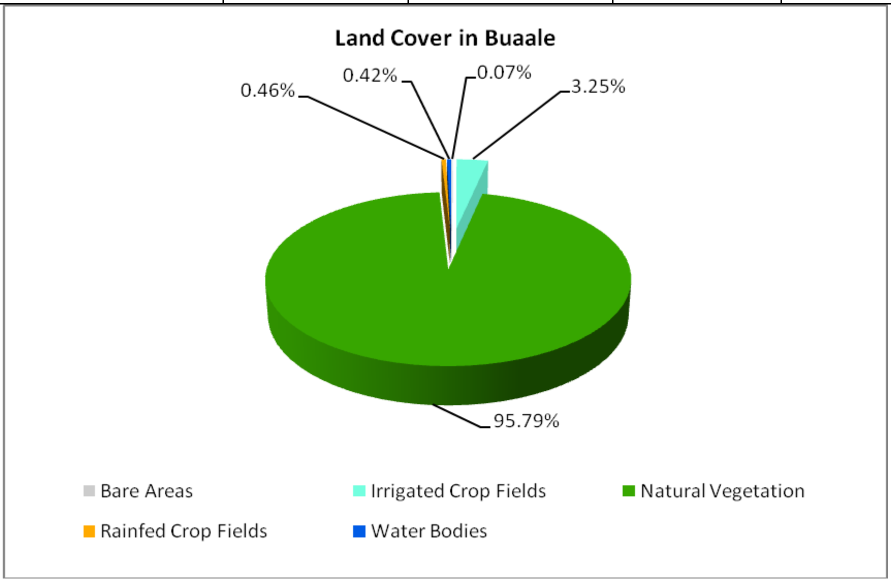
Land Cover Types Bulo_Burto District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	53	0.08	1324.404	13
Builtup Areas	30	0.05	749.6627	7.5
Irrigated Crop Fields	843	1.30	21065.52	21.1
Natural Vegetation	57903	89.43	1446924	14469
Rainfed Crop Fields	5911	9.13	147708.5	1477.8
Water Bodies	6	0.01	149.9325	1.5
Total	**64746**	**100.00**	**1,617,922**	**16179**



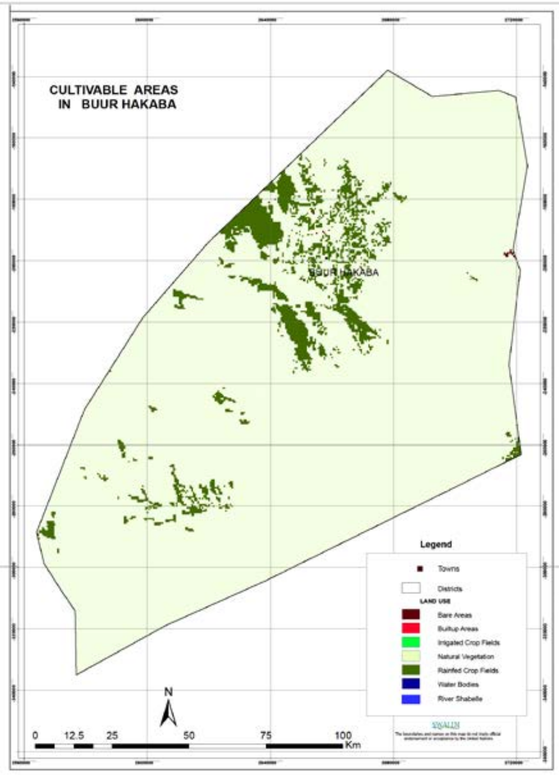
11. BUÁALE DISTRICT



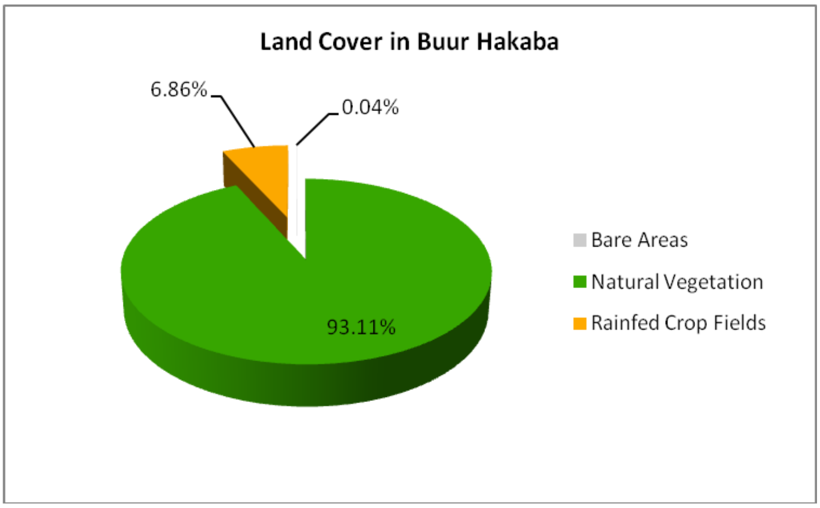
Land Cover Type Buaale District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	15	0.07	375.3518	3.75
Irrigated Crop Fields	713	3.25	17841.72	178
Natural Vegetation	21036	95.80	526393.4	5263.69
Rainfed Crop Fields	102	0.46	2552.392	25.52
Water Bodies	93	0.42	2327.181	23.27
Total	**21959**	**100.00**	**549,490**	**5494.23**



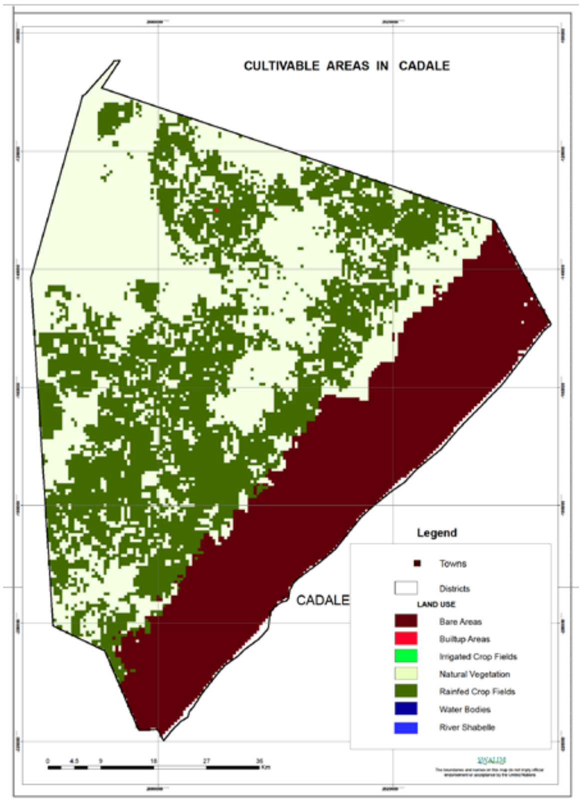
12. BUUR HAKABA DISTRICT



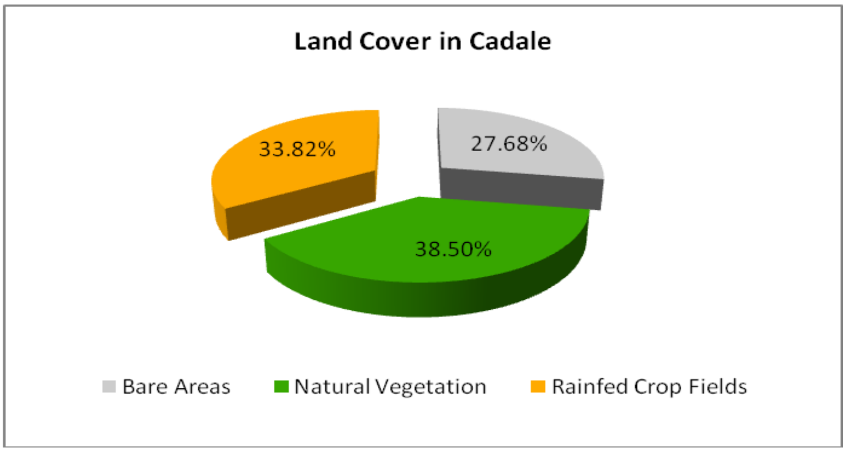
Land Cover Types Buur Hakaba District	**No. of Dots**	**Percentage%**	**Area (Ha)**	**Area (sq.km)**
Bare Areas	24	0.04	659.8768	6.6
Natural Vegetation	61018	93.11	1677682	16777
Rainfed Crop Fields	4493	6.86	123534.4	1235
Total	**65535**	**100.00**	**1,801,876**	**18018.6**



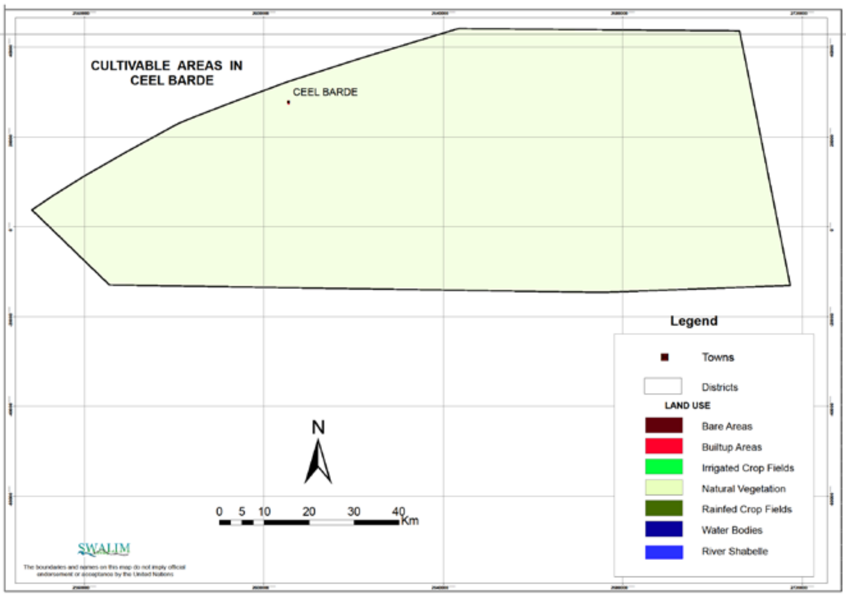
13. CADALE DISTRICT



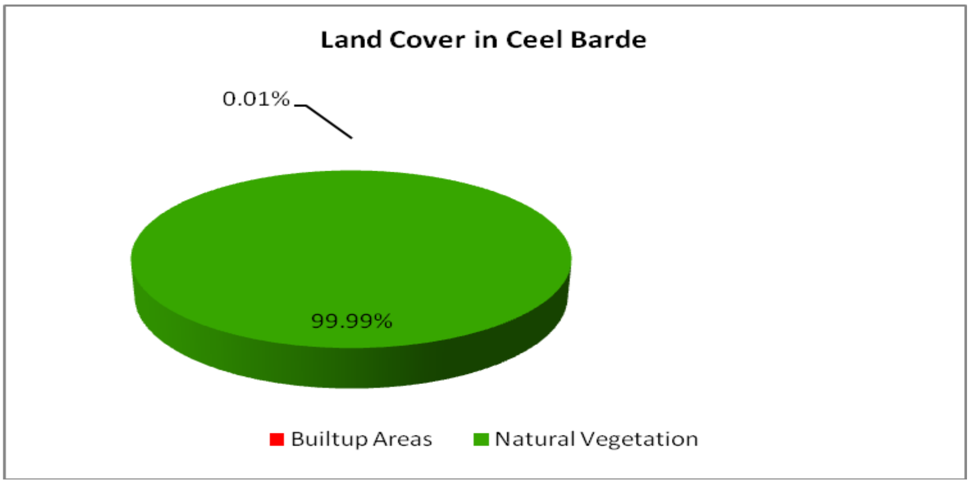
Land Cover Type Cadale District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	6415	27.68	161265.1	1612.65
Natural Vegetation	8925	38.50	224363.3	2243.63
Rainfed Crop Fields	7839	33.82	197062.6	1970.62
Total	**23179**	**100.00**	**582,691**	**5826.9**



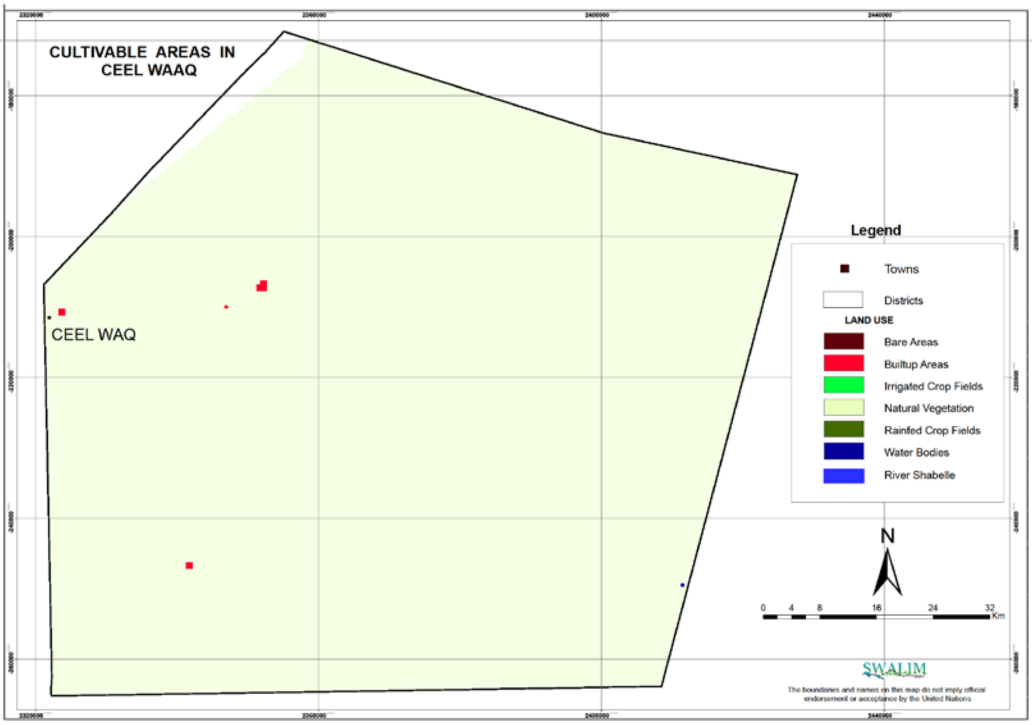
14. CEEL_BARDE DISTRICT



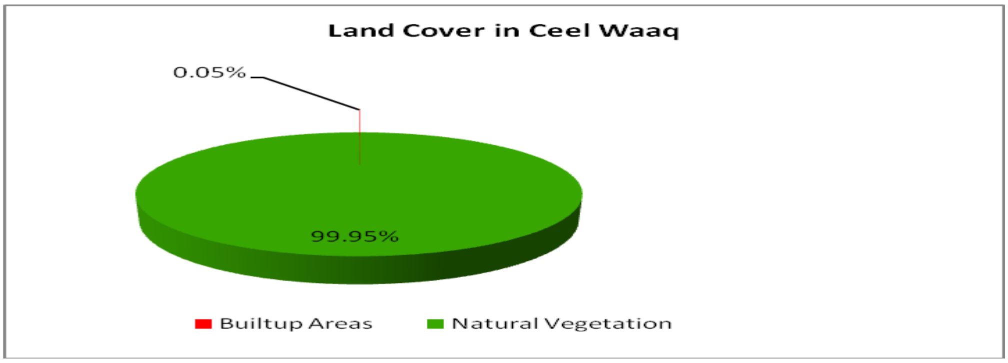
Land Cover Types Ceel_Barde District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq. km)
Builtup Areas	2	0.01	47.9754	0.48
Natural Vegetation	32029	99.99	768302	7683.02
Total	**32031**	**100.00**	**768,350**	**7683.5**



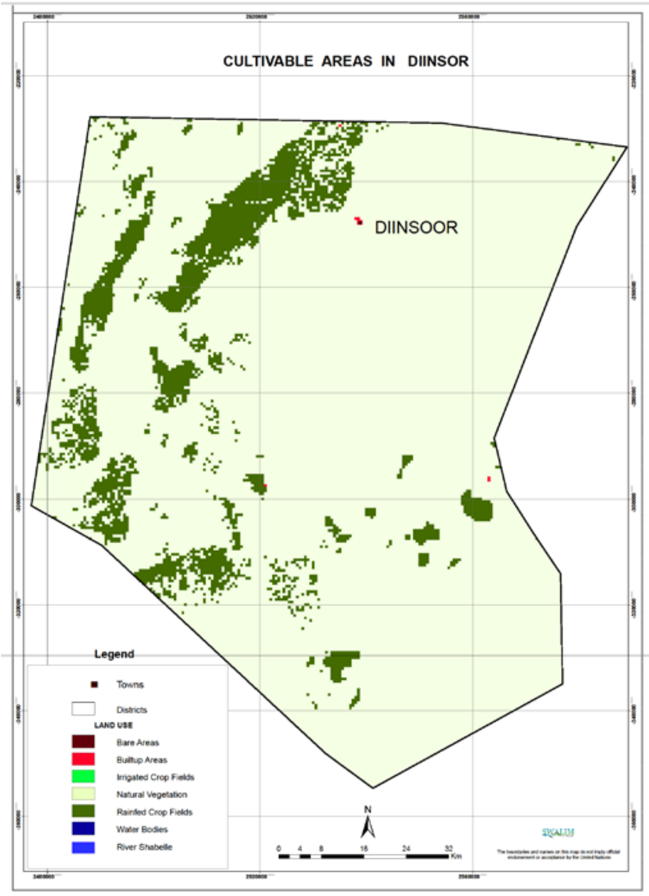
15. CEEL_WAAQ DISTRICT



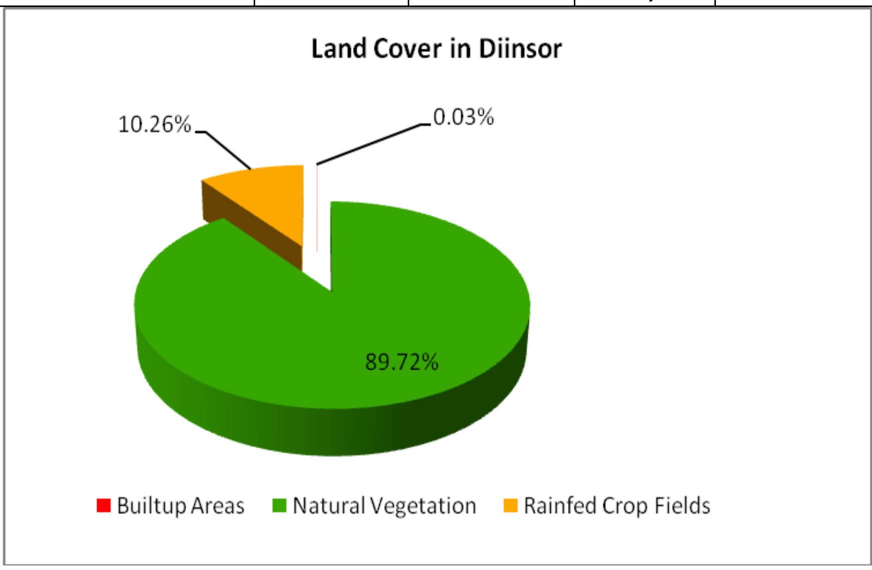
Land Cover Type Ceel_Waaq District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Builtup Areas	17	0.05	403.289	4.03
Natural Vegetation	33077	99.95	784681.7	7846.82
Total	**33094**	**100.00**	**785,085**	**7850.85**



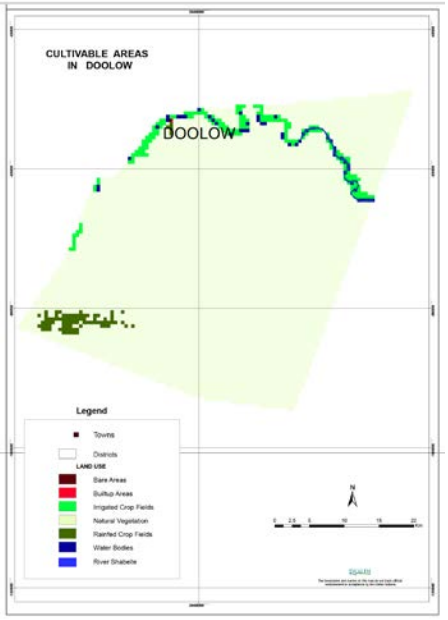
16. DIINSOR DISTRICT



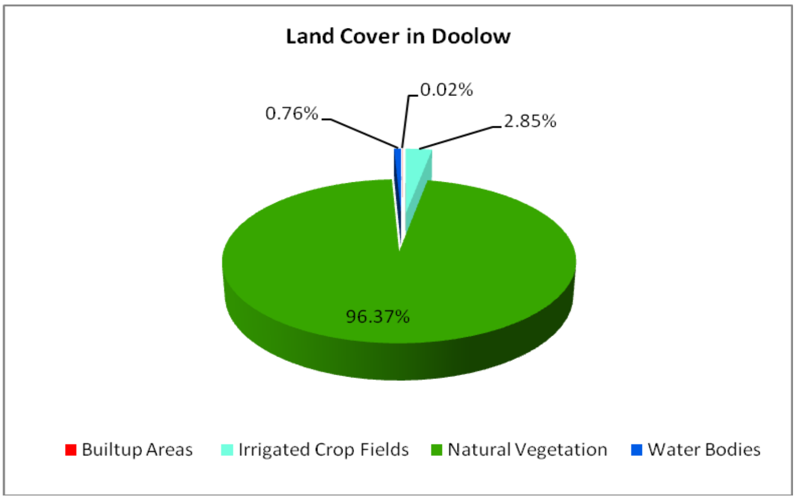
Land Cover Types Diinsor District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Builtup Areas	10	0.03	248.6793	2.49
Natural Vegetation	35135	89.72	873734.8	8737.35
Rainfed Crop Fields	4017	10.26	99894.49	998.94
Total	**39162**	**100.00**	**973,878**	**9738.78**



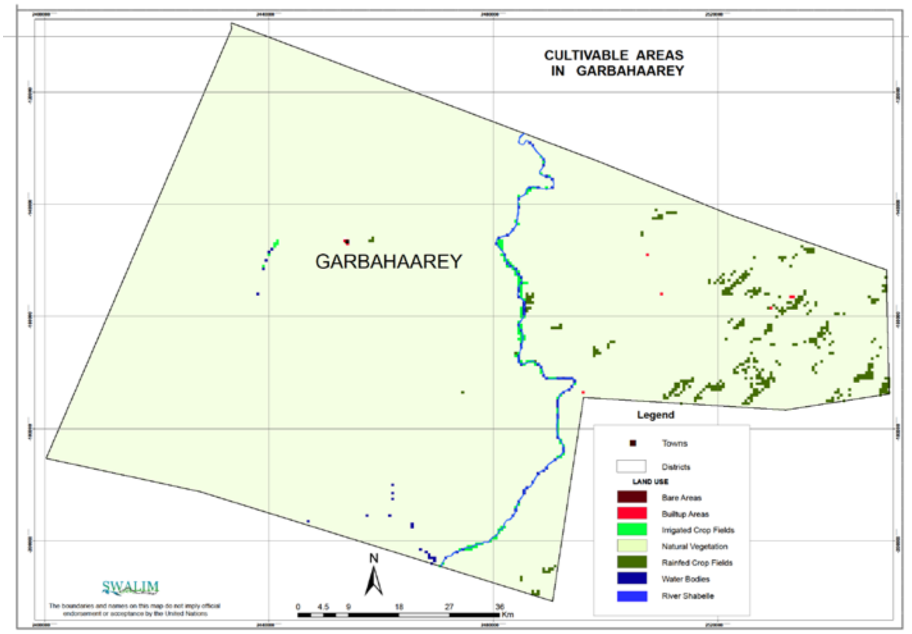
17. DOOLOW DISTRICT



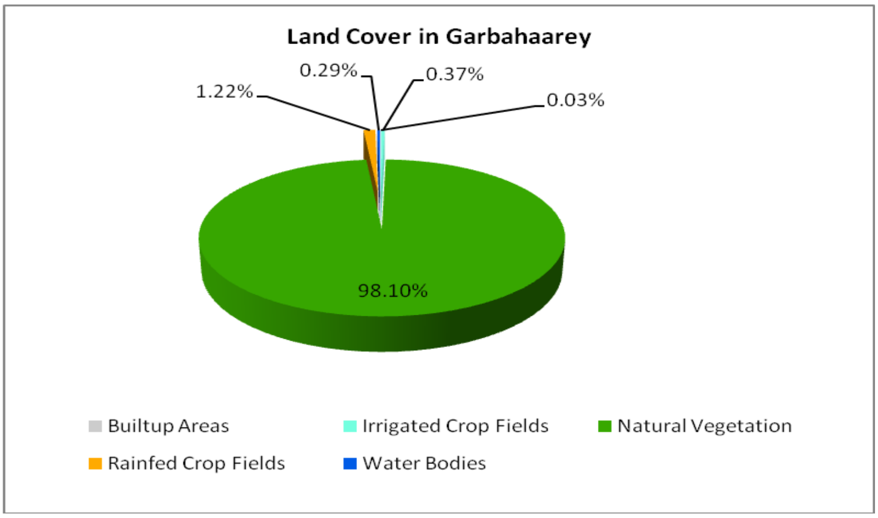
Land Cover Types Doolow District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Builtup Areas	1	0.02	26	0.26
Irrigated Crop Fields	180	2.85	4653	46.52
Natural Vegetation	6085	96.37	157281	1572.81
Water Bodies	48	0.76	1241	12.41
Total	**6314**	**100.00**	**163200**	**1632**



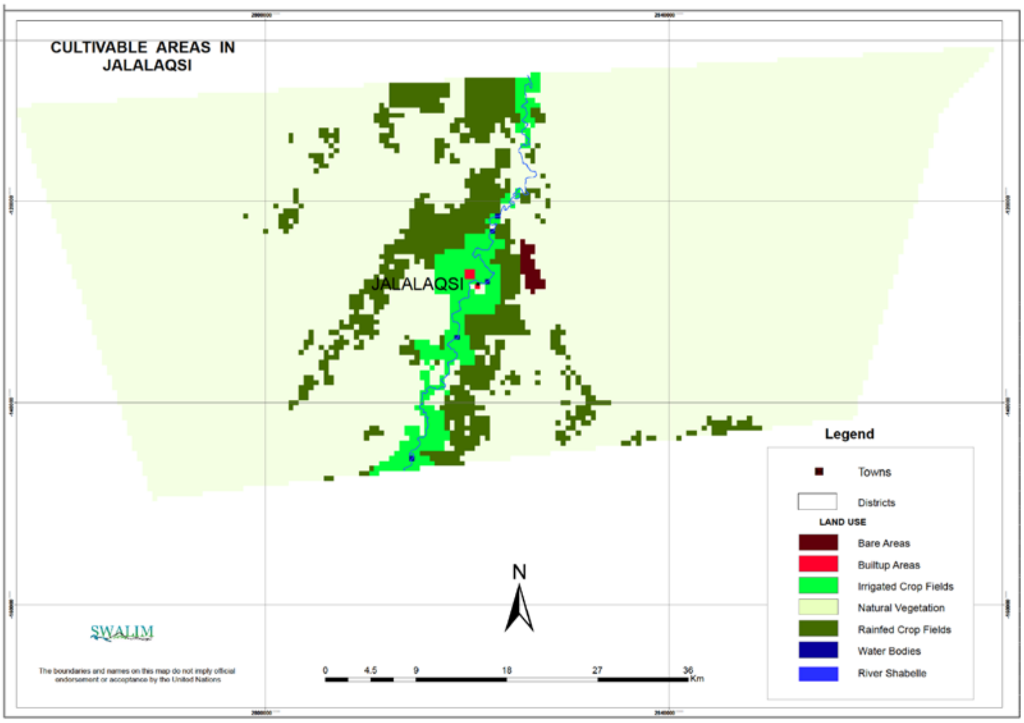
18. GARBAHAAREY DISTRICT



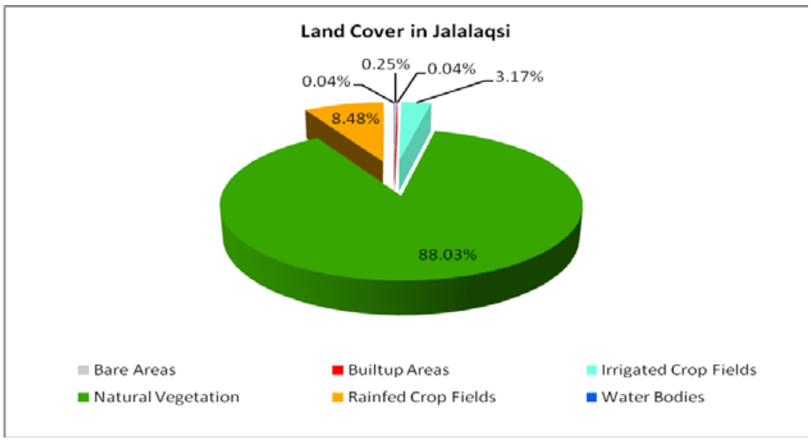
Land Cover Type Garbahaarey District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Builtup Areas	9	0.03	225.2298	2.25
Irrigated Crop Fields	123	0.37	3078.141	30.78
Natural Vegetation	32654	98.10	817183.9	8171.84
Rainfed Crop Fields	405	1.22	10135.34	101.35
Water Bodies	95	0.29	2377.426	23.77
Total	**33286**	**100.00%**	**833,000**	**8330**



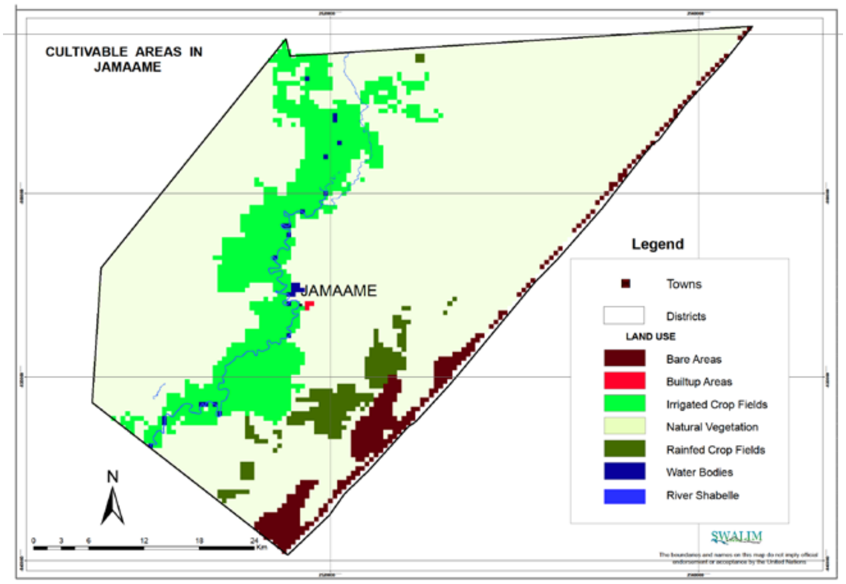
19. JALALAQSI DISTRICT



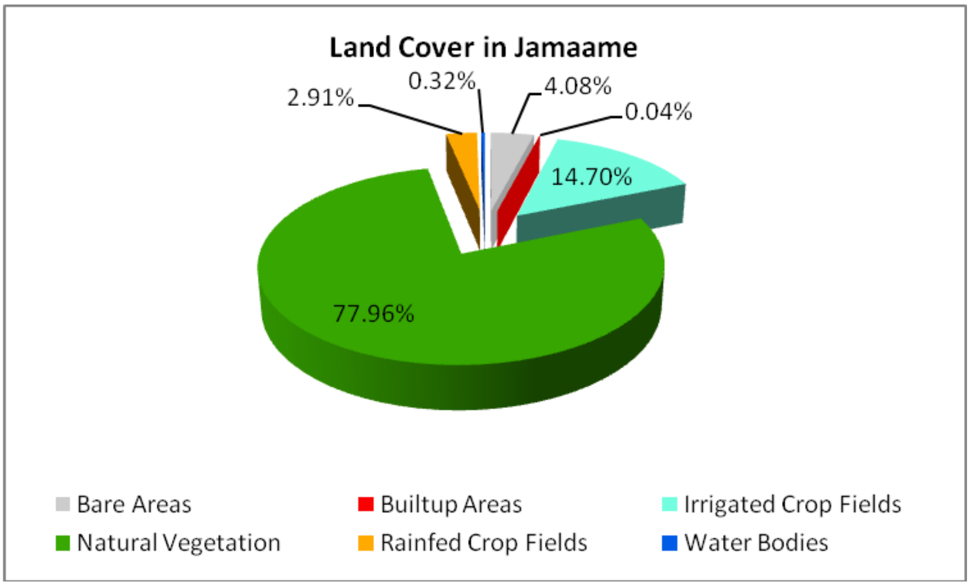
Land Cover Type Jalalaqsi District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	31	0.25	774.2875	7.74
Builtup Areas	5	0.04	124.8851	1.25
Irrigated Crop Fields	394	3.17	9840.945	98.41
Natural Vegetation	10954	88.03	273598.2	2736
Rainfed Crop Fields	1055	8.48	26350.75	263.51
Water Bodies	5	0.04	124.8851	1.25
Total	**12444**	**100.00**	**310,814**	**3108.16**



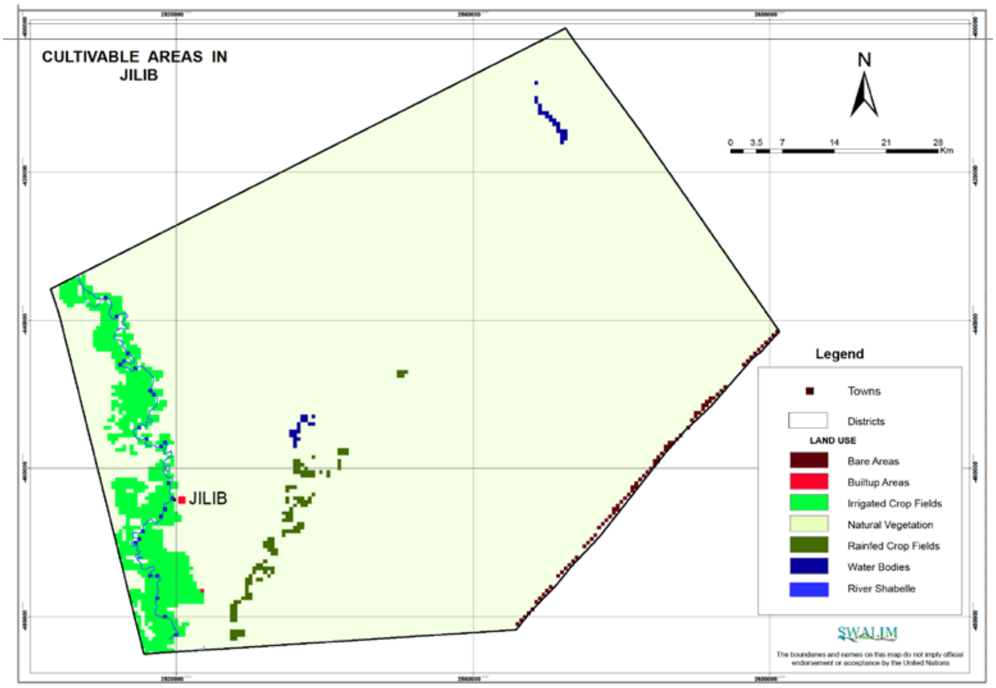
20. JAMAAME DISTRICT



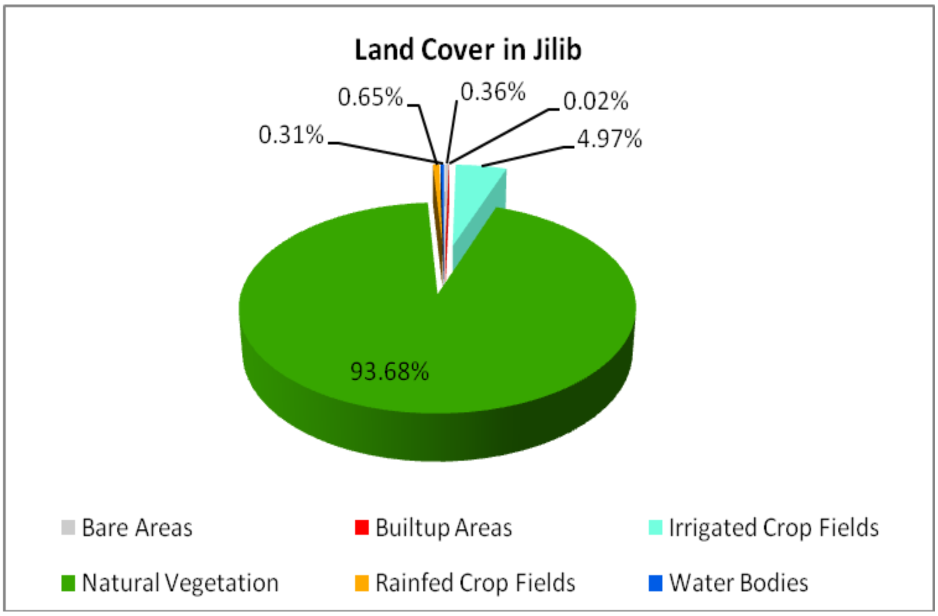
Land Cover in Jamaame District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	347	4.08	8784	88
Builtup Areas	3	0.04	76	1
Irrigated Crop Fields	1249	14.70	31617	316
Natural Vegetation	6626	77.96	167728	1677
Rainfed Crop Fields	247	2.91	6252	63
Water Bodies	27	0.32%	683	7
Total	**8499**	**100.00%**	**215140**	**2151**



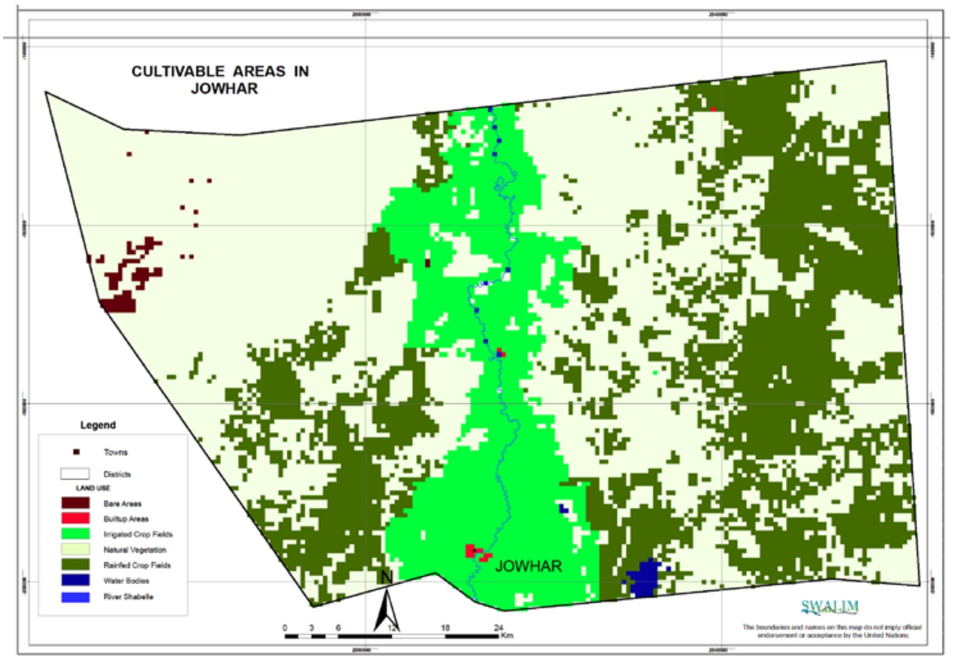
21. JILIB DISTRICT



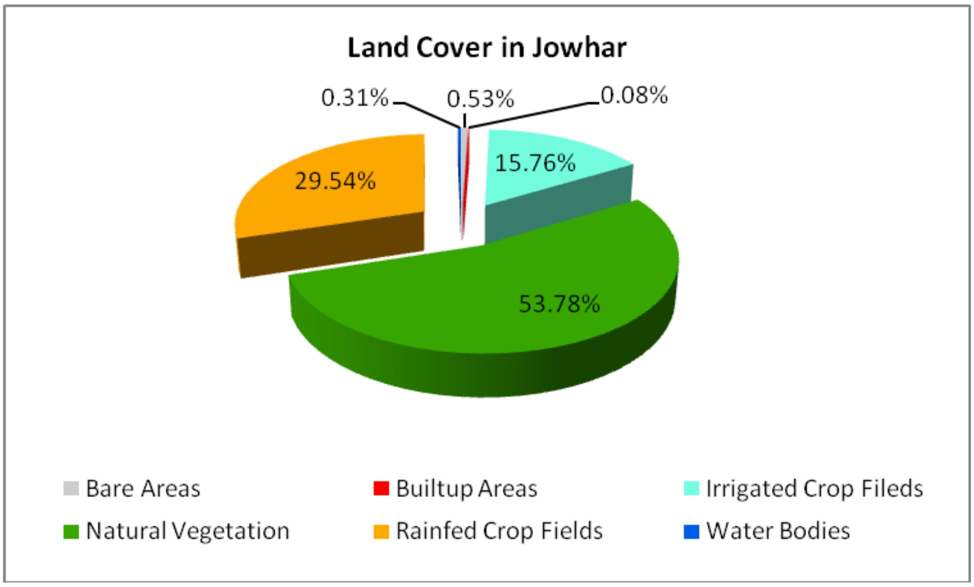
Land Cover in Jilib District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	76	0.36	1905	19
Builtup Areas	5	0.02	125	1
Irrigated Crop Fields	1042	4.97	26114	261
Natural Vegetation	19622	93.68	491761	4918
Rainfed Crop Fields	136	0.65	3408	34
Water Bodies	65	0.31	1629	16
Total	20946	100.00	524943	5249



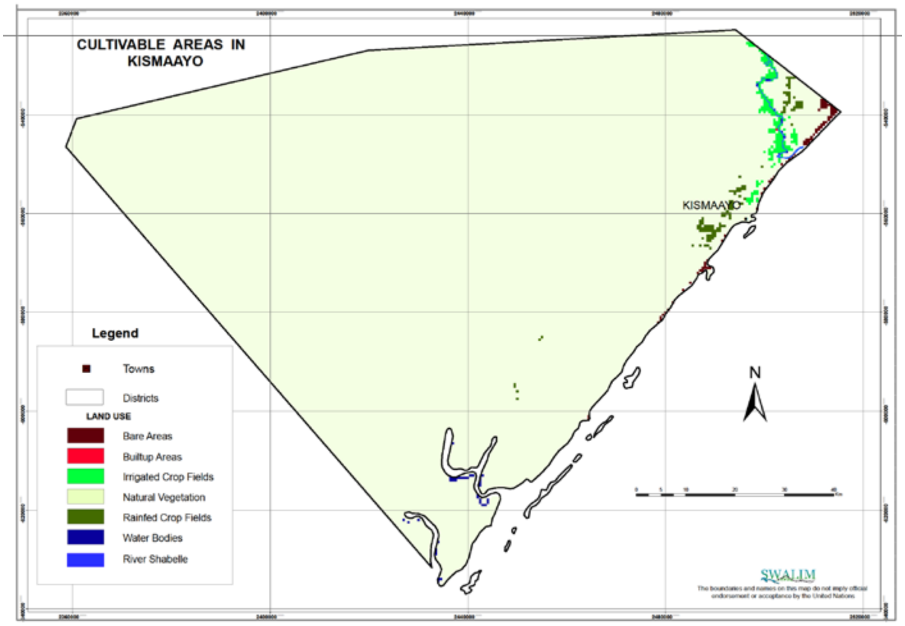
22. JOWHAR DISTRICT



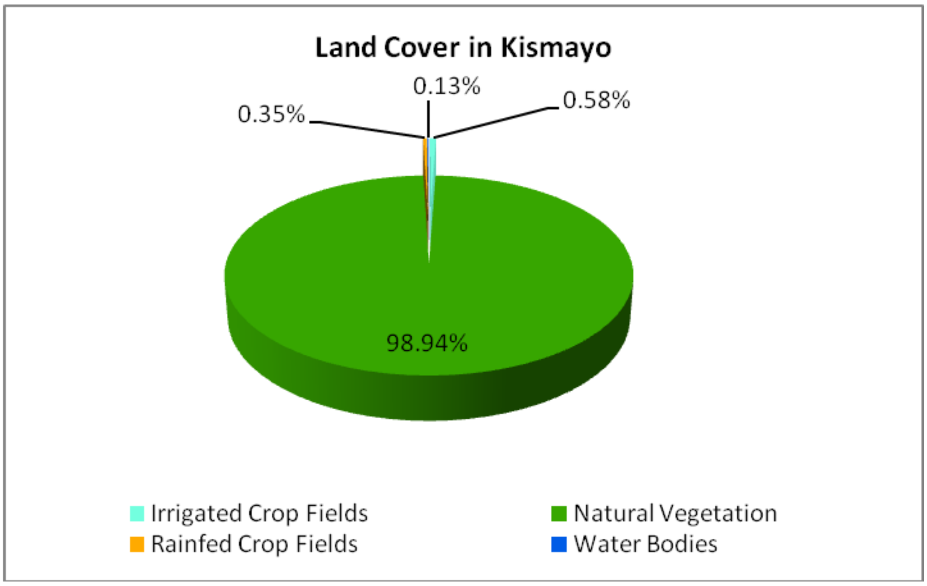
Land Cover in Jowhar District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	98	0.53	2448	24
Builtup Areas	15	0.08	375	4
Irrigated Crop Fileds	2923	15.76	73029	730
Natural Vegetation	9975	53.78	249217	2492
Rainfed Crop Fields	5480	29.54	136913	1369
Water Bodies	57	0.31	1424	14
	18548	100.00	463407	4634



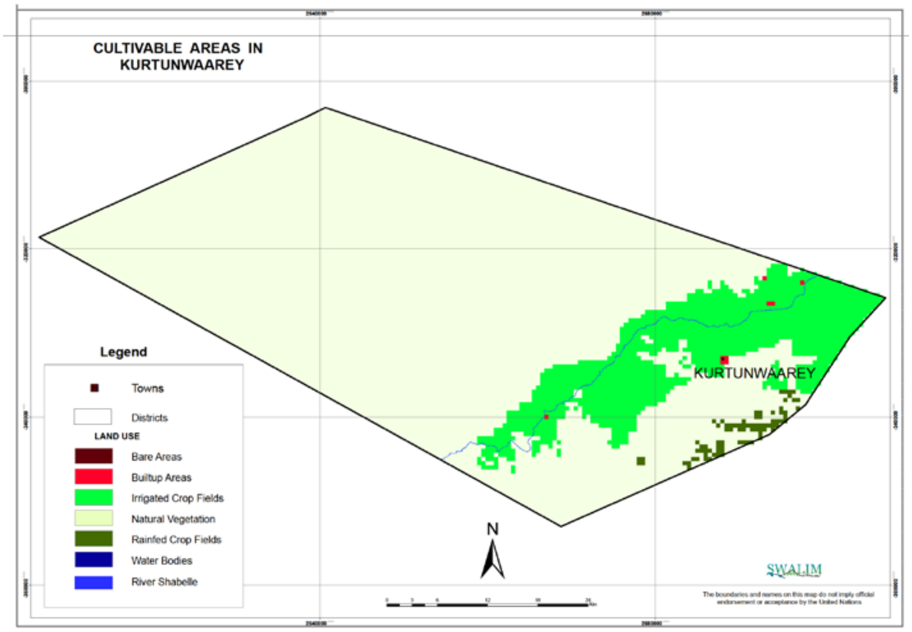
23. KISMAAYO DISTRICT



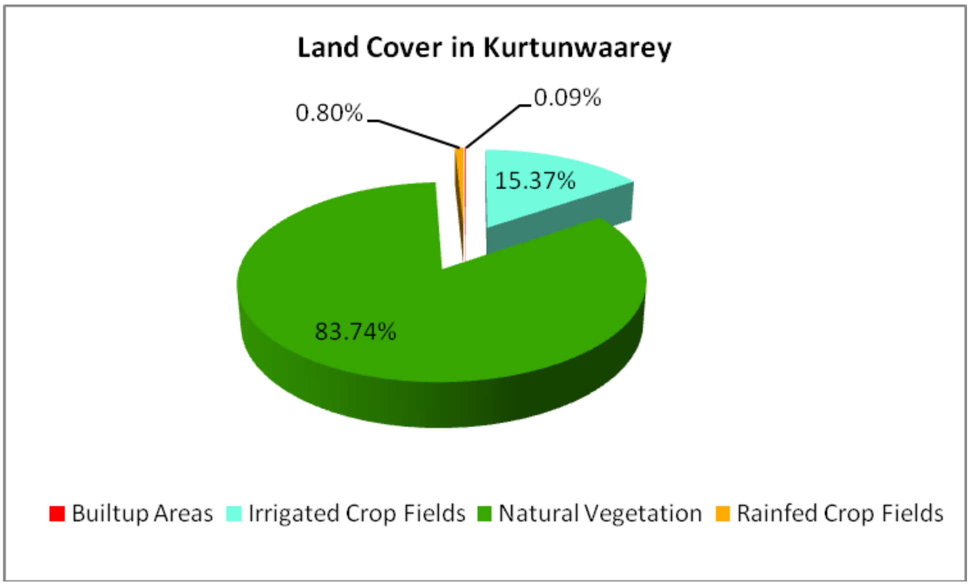
Land Cover in Kismayu District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Irrigated Crop Fields	211	0.58	5319	53
Natural Vegetation	36260	98.94	914046	9140
Rainfed Crop Fields	130	0.35	3277	33
Water Bodies	48	0.13	1210	12
Total	36649	100.00	923852	9239



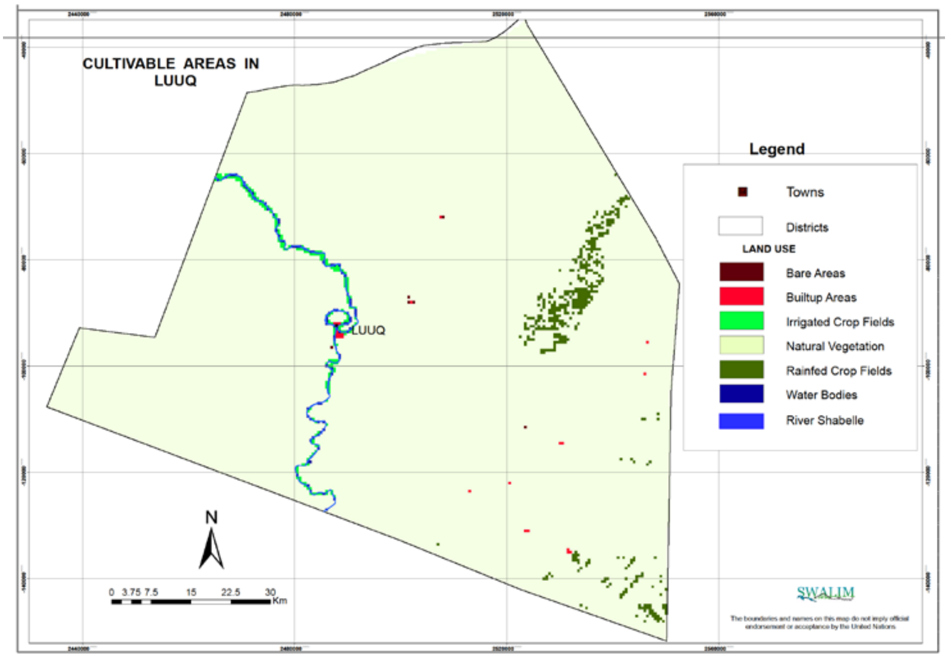
24. KURTUNWAAREY DISTRICT



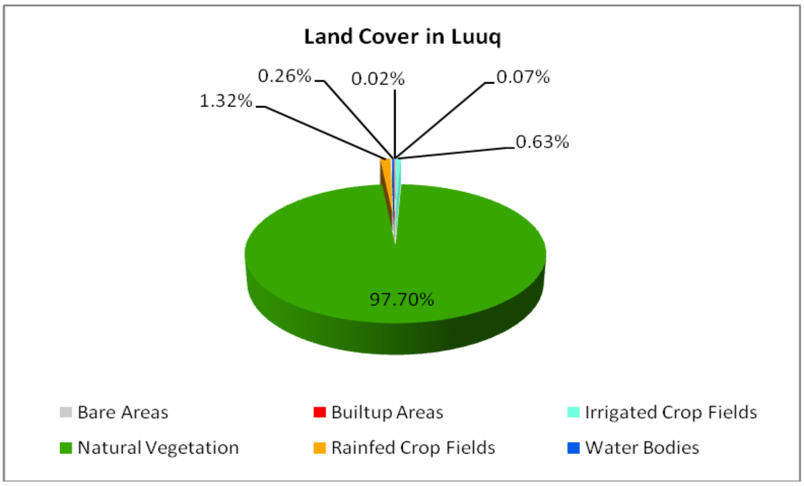
Land Cover in Kurtunwaarey District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Builtup Areas	9	0.09	225	2
Irrigated Crop Fields	1566	15.37	39115	391
Natural Vegetation	8531	83.74	213084	2131
Rainfed Crop Fields	82	0.80	2048	20
Total	10188	100.00	254472	2545



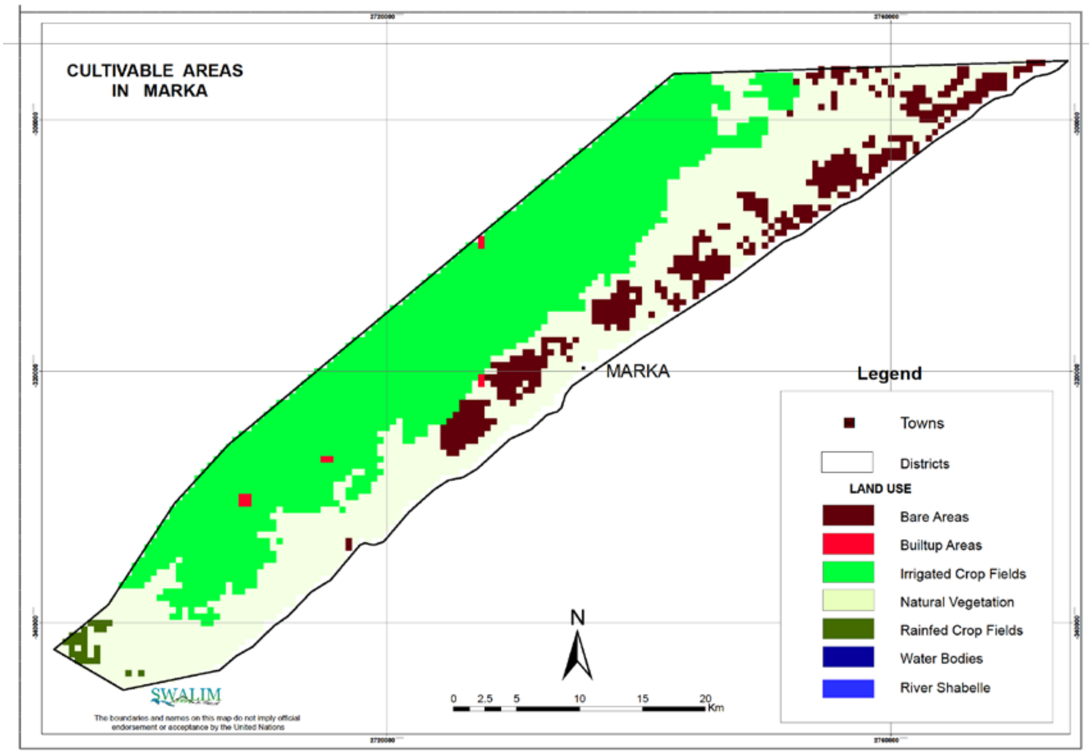
25. LUUQ DISTRICT



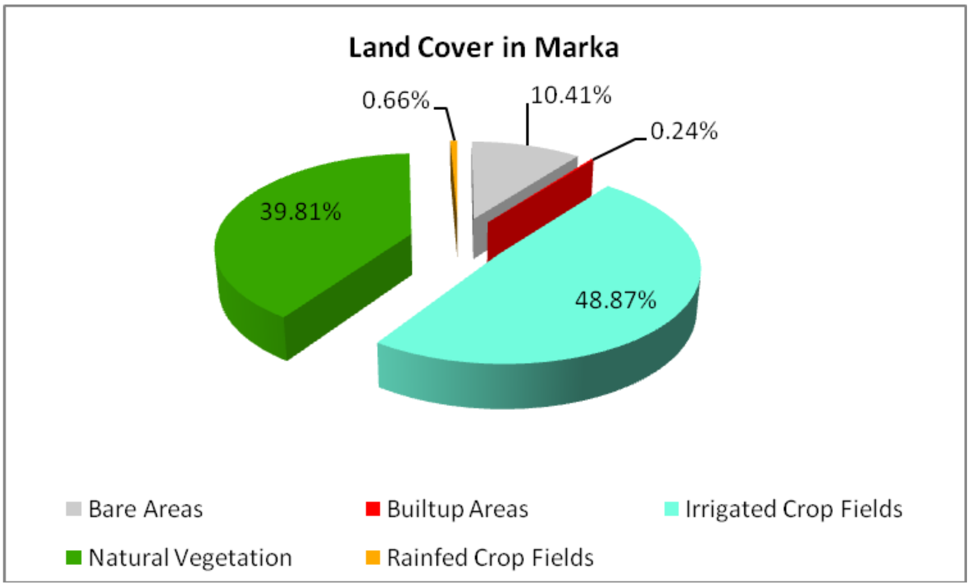
Land Cover in Luuq District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	6	0.02	150	2
Builtup Areas	24	0.07	602	6
Irrigated Crop Fields	209	0.63	5242	52
Natural Vegetation	32233	97.70	808395	8084
Rainfed Crop Fields	435	1.32	10910	109
Water Bodies	86	0.26	2157	22
Total	32993	100.00	827456	8275



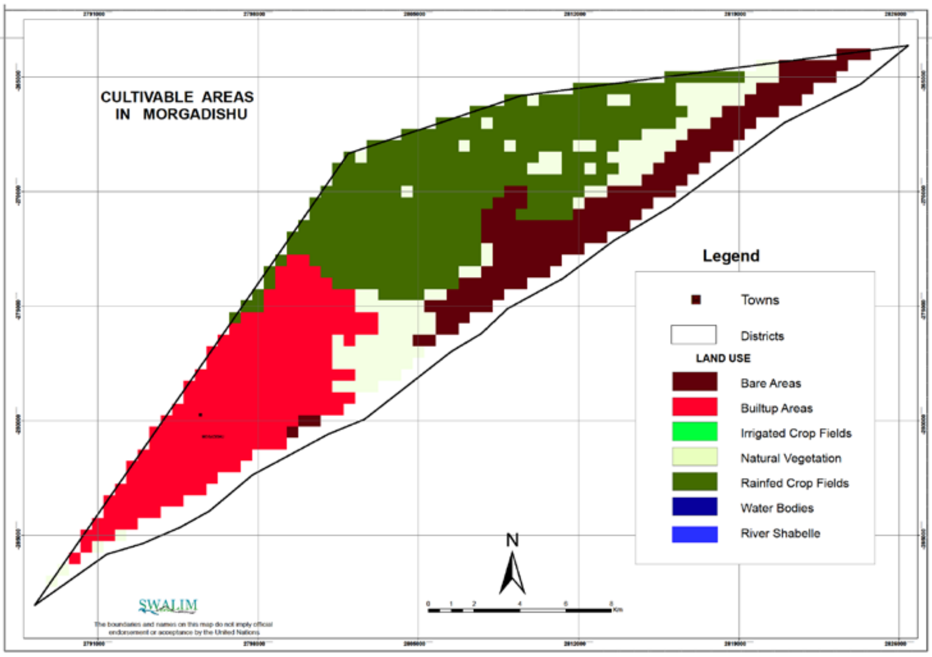
26. MARKA DISTRICT



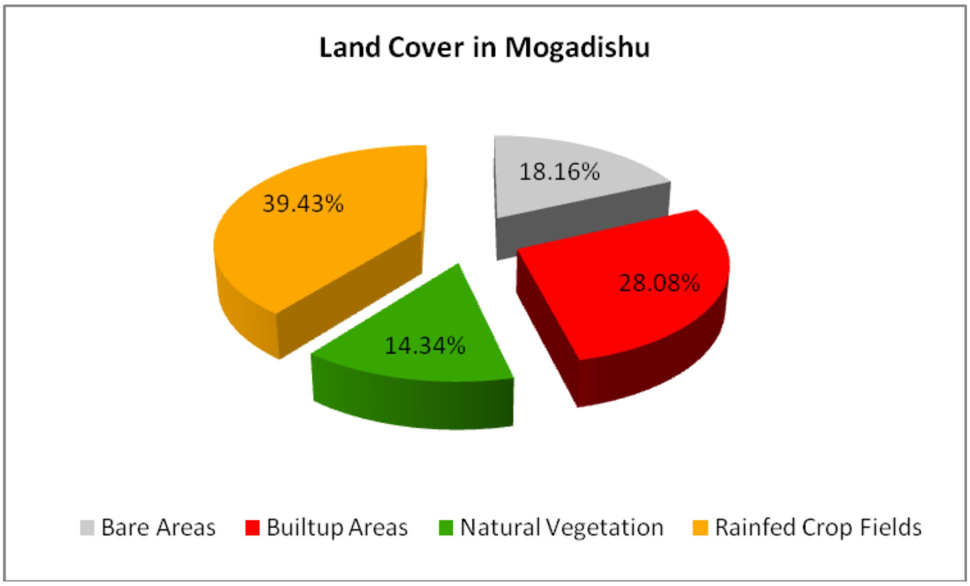
Land Cover in Marka District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	425	10.41	11085	111
Builtup Areas	10	0.24	261	3
Irrigated Crop Fields	1996	48.87	52061	521
Natural Vegetation	1626	39.81	42410	424
Rainfed Crop Fields	27	0.66	704	7
Total	4084	100.00	106521	1065



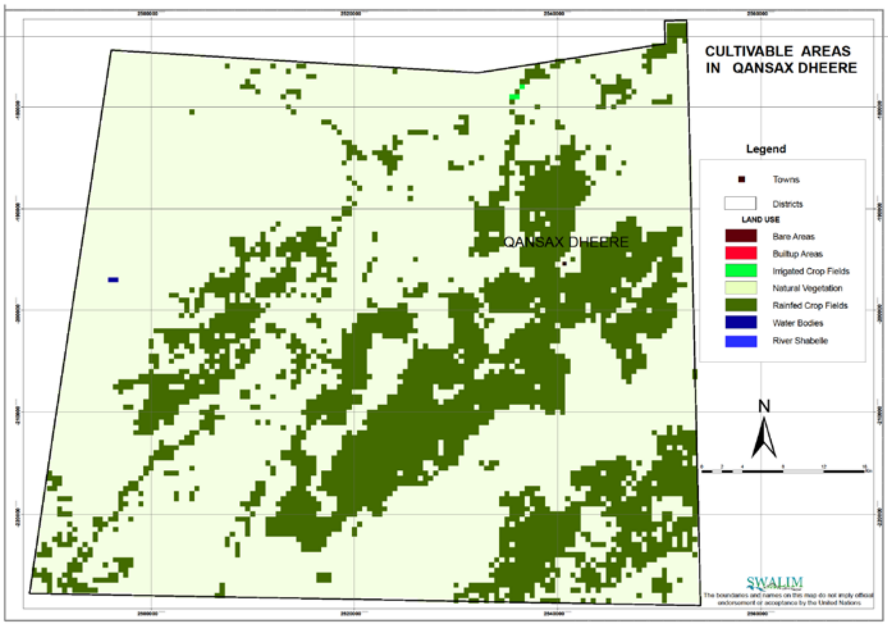
27. MOGADISHU DISTRICT



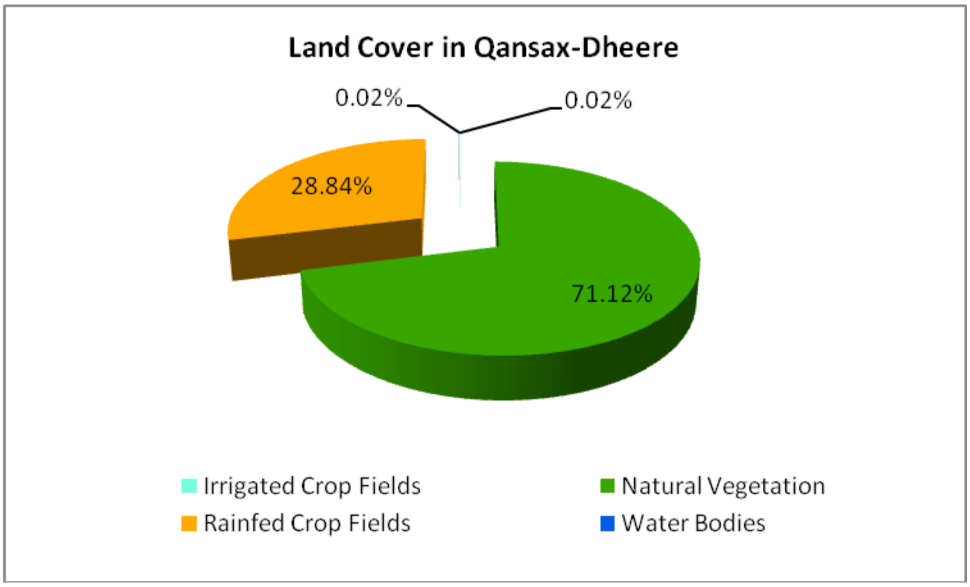
Land Cover in Mogadishu District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	152	18.16	4292	43
Builtup Areas	235	28.08	6635	66
Natural Vegetation	120	14.34	3388	34
Rainfed Crop Fields	330	39.43	9318	93
Total	837	100.00	23633	236



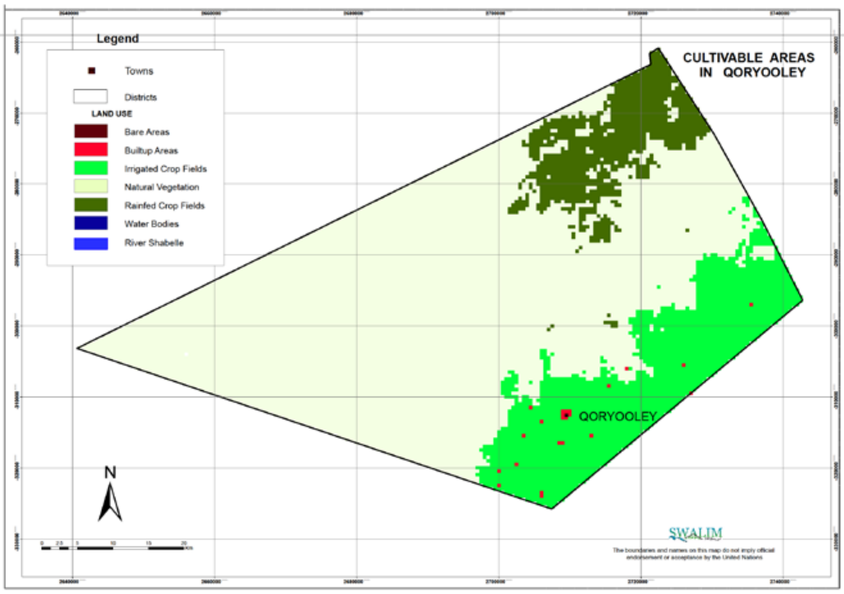
28. QANSAX DHEERE DISTRICT



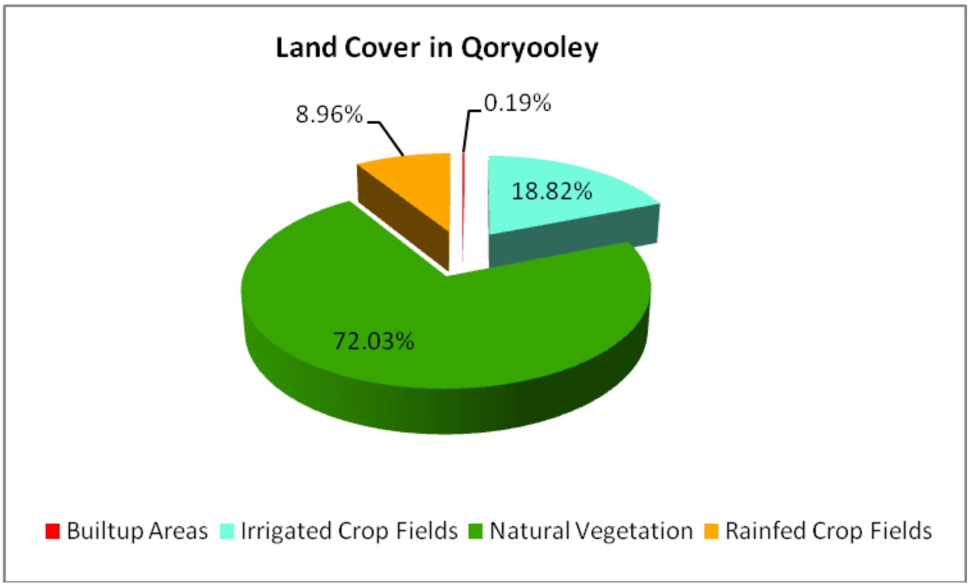
Land Cover in Qansax Dheere District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Irrigated Crop Fields	3	0.02	75	1
Natural Vegetation	9283	71.12	232490	2325
Rainfed Crop Fields	3764	28.84	94268	943
Water Bodies	2	0.02	50	1
Total	13052	100.00	326883	3269



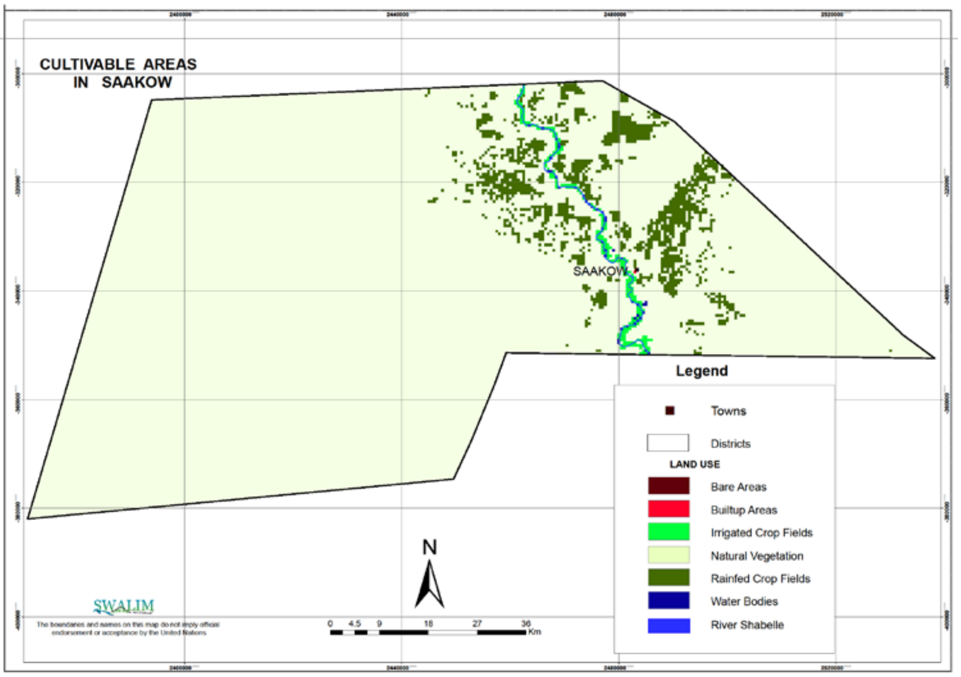
29. QORYOOLEY DISTRICT



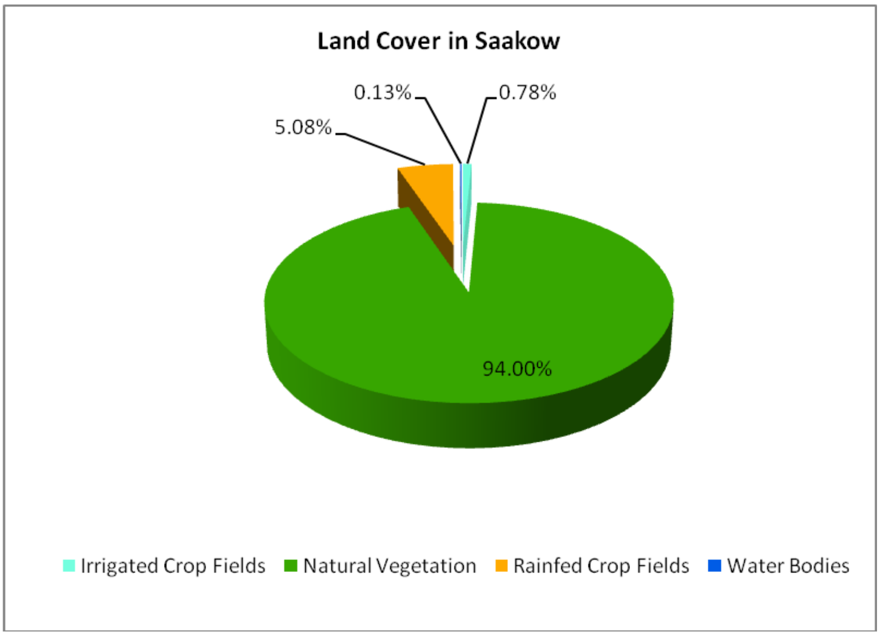
Land Cover in Qoryooley District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Builtup Areas	24	0.19%	600	6
Irrigated Crop Fields	2419	18.82%	60431	604
Natural Vegetation	9260	72.03%	231333	2313
Rainfed Crop Fields	1152	8.96%	28779	288
Total	12855	100.00%	321143	3211



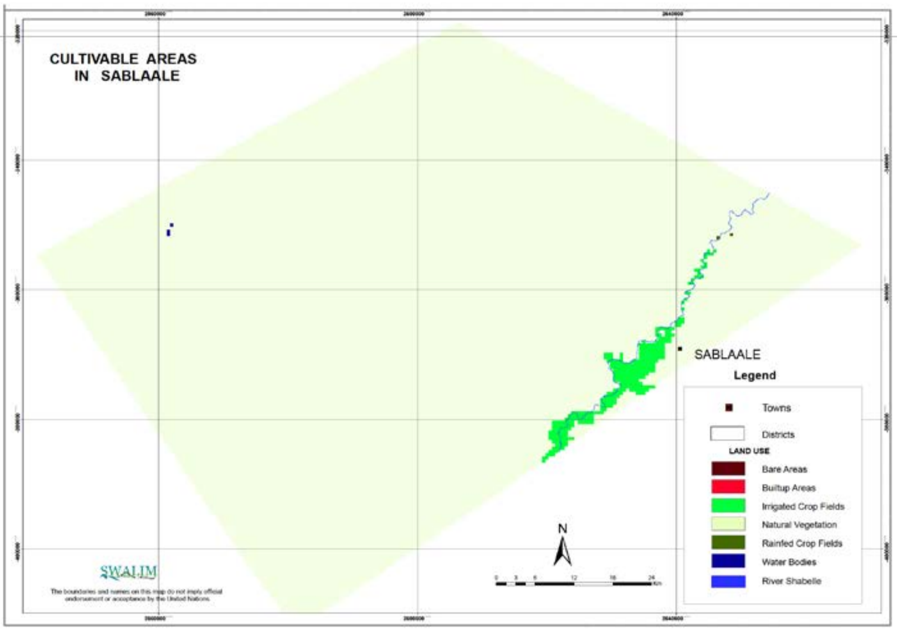
30. SAAKOW DISTRICT



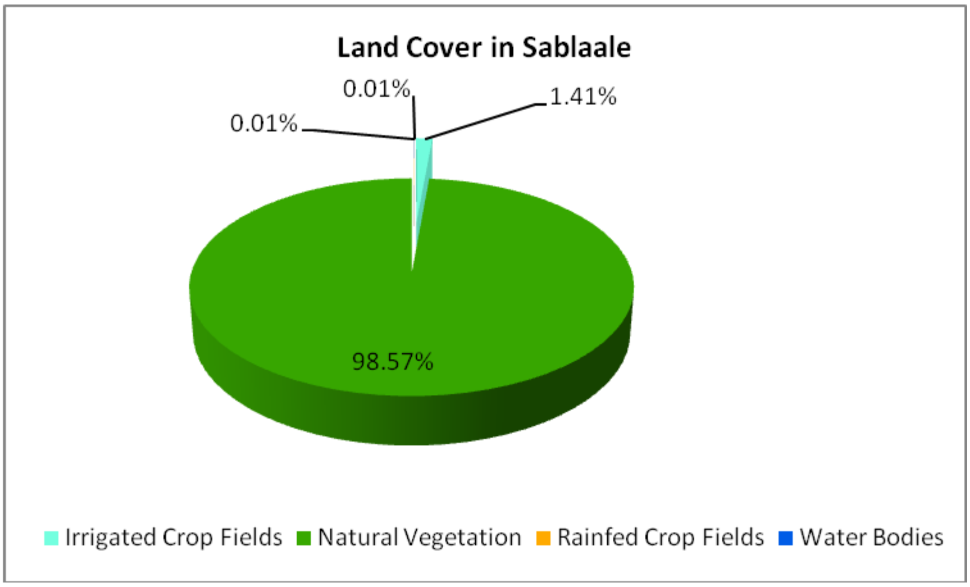
Land Cover in Saakow District	No. of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Irrigated Crop Fields	252	0.78%	6310	63
Natural Vegetation	30268	94.00%	757895	7579
Rainfed Crop Fields	1637	5.08%	40990	410
Water Bodies	42	0.13%	1052	11
Total	32199	100.00%	806246	8062



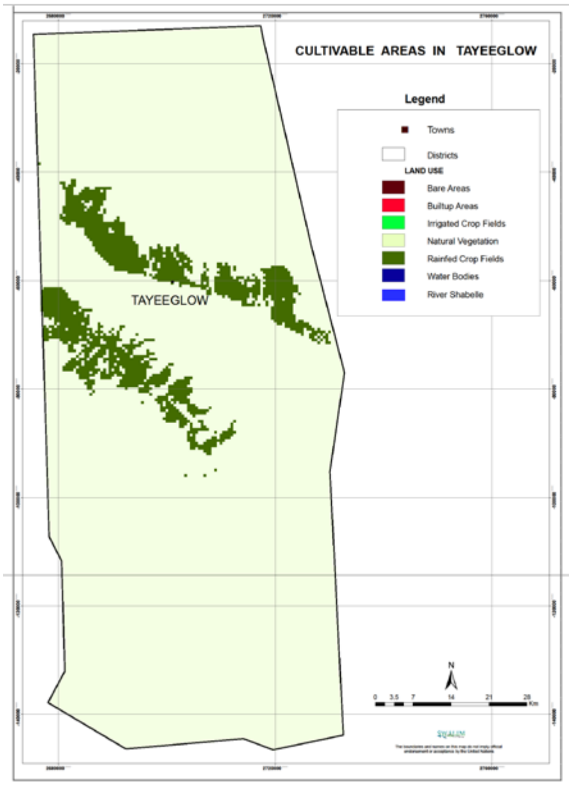
31. SABLAALE DISTRICT



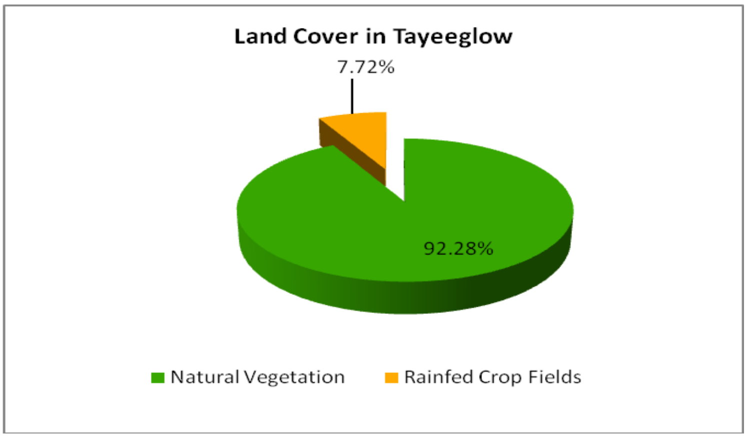
Land Cover in Sablaale District	No of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Irrigated Crop Fields	337	1.41%	8428	84
Natural Vegetation	23621	98.57%	590737	5907
Rainfed Crop Fields	2	0.01%	50	1
Water Bodies	3	0.01%	75	1
Total	23963	100.00%	599290	5993



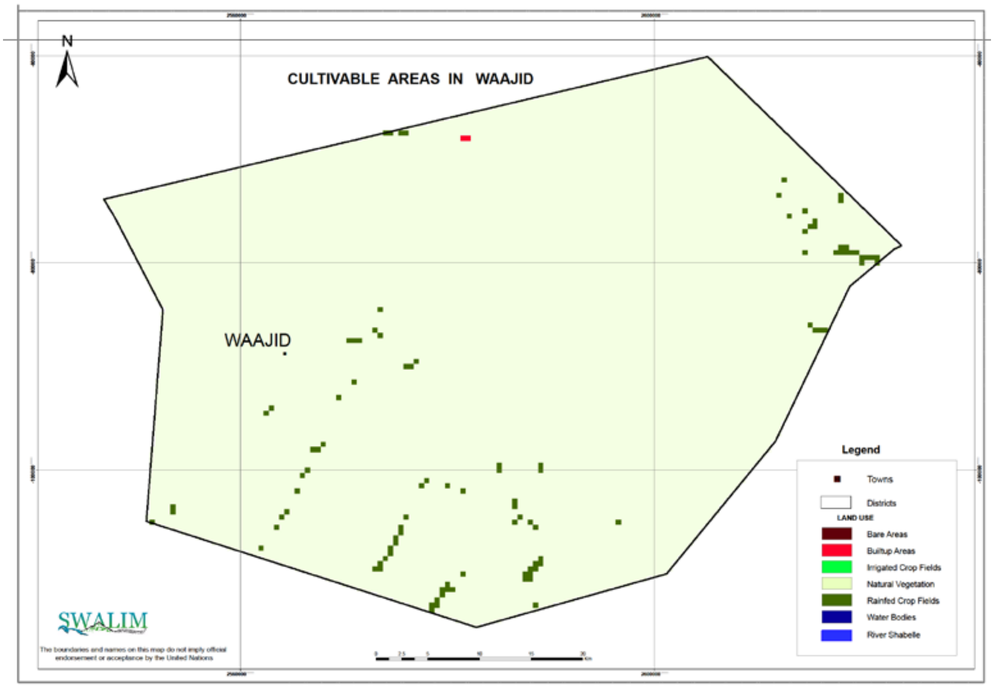
32. TAYEEGLOW DISTRICT



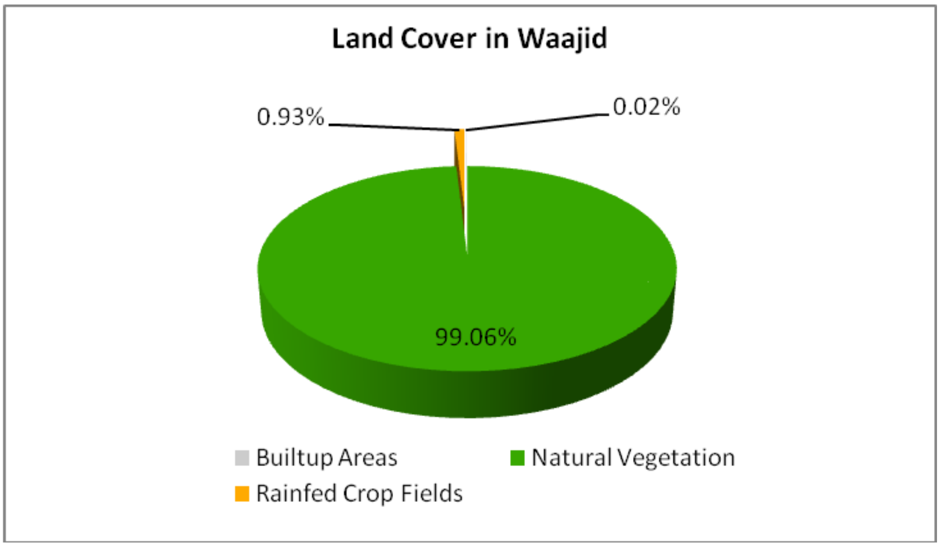
Land Cover in Tayeeglow District	No of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Natural Vegetation	24360	92.28	608336	6083
Rainfed Crop Fields	2037	7.72	50869	509
Total	26397	100.00	659205	6592



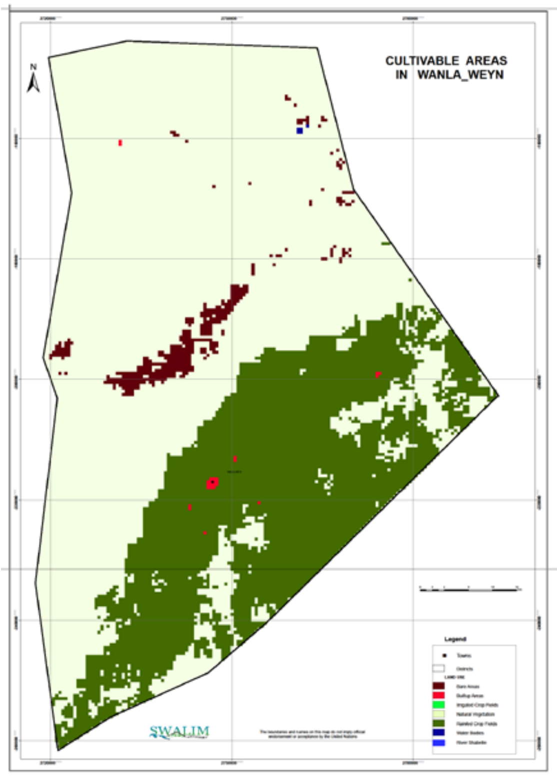
33. WAJID DISTRICT



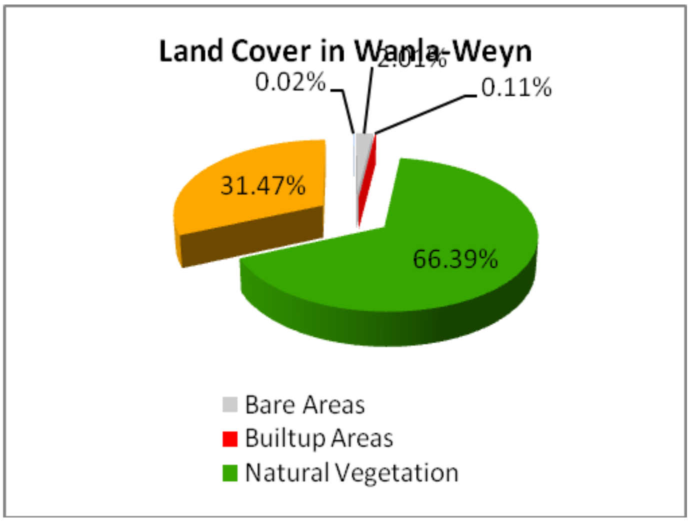
Land Cover in Waajid District	**No of Dots**	**Percentage (%)**	**Area (Ha)**	**Area (sq.km)**
Builtup Areas	2	0.02	50	1
Natural Vegetation	11113	99.06	277716	2777
Rainfed Crop Fields	104	0.93	2599	26
Total	11219	100.00	280365	2804



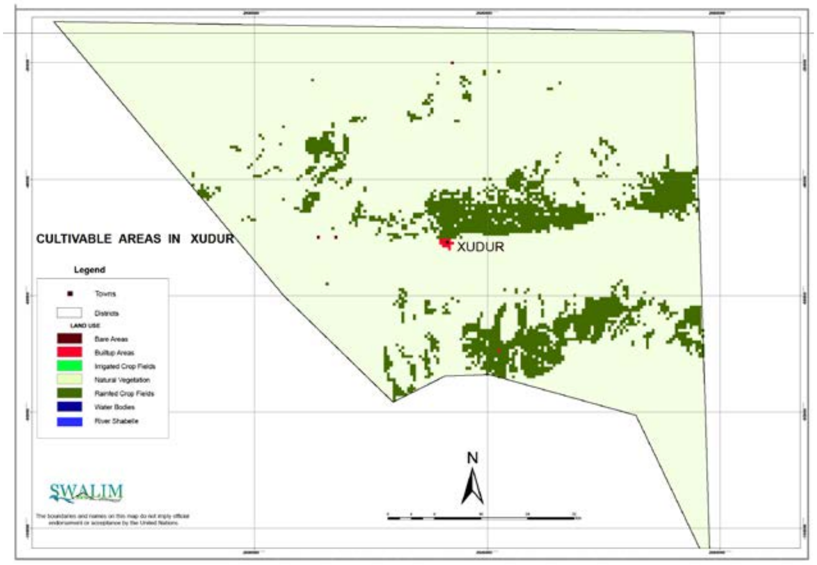
34. WANLA WEYN DISTRICT



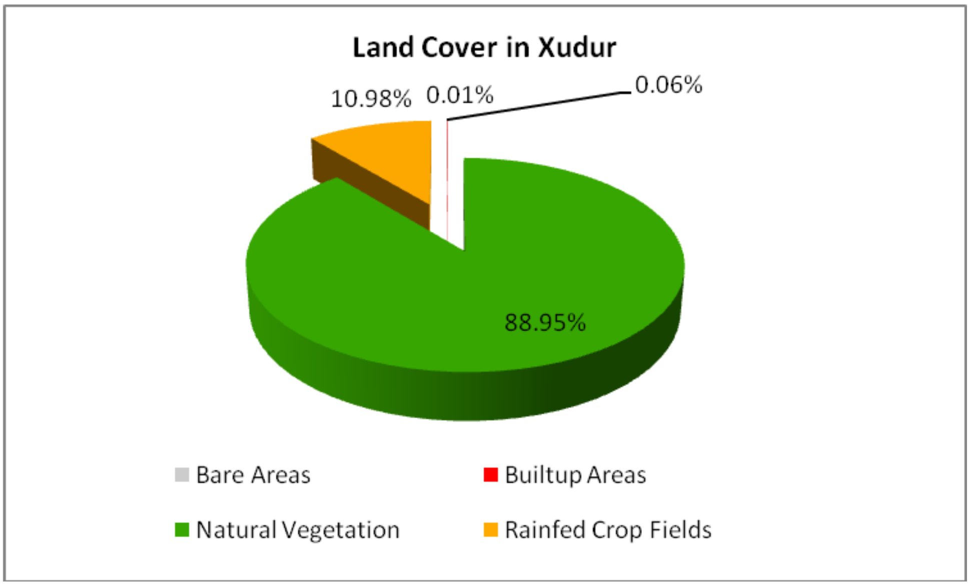
Land Cover in Wanla_Weyn District	No of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	460	2.01	11490	115
Builtup Areas	25	0.11	624	6
Natural Vegetation	15172	66.39	378957	3790
Rainfed Crop Fields	7191	31.47	179613	1796
Water Bodies	5	0.02	125	1
Total	22853	100.00	570809	5708



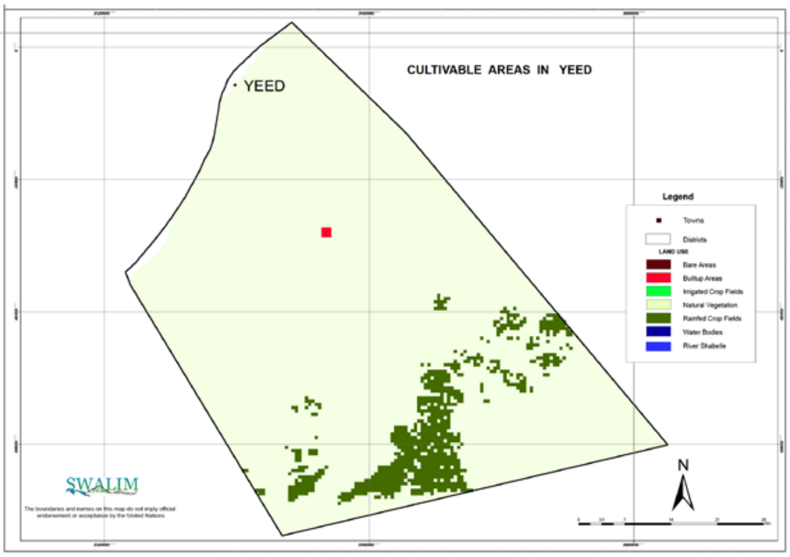
35. XUDUR DISTRICT



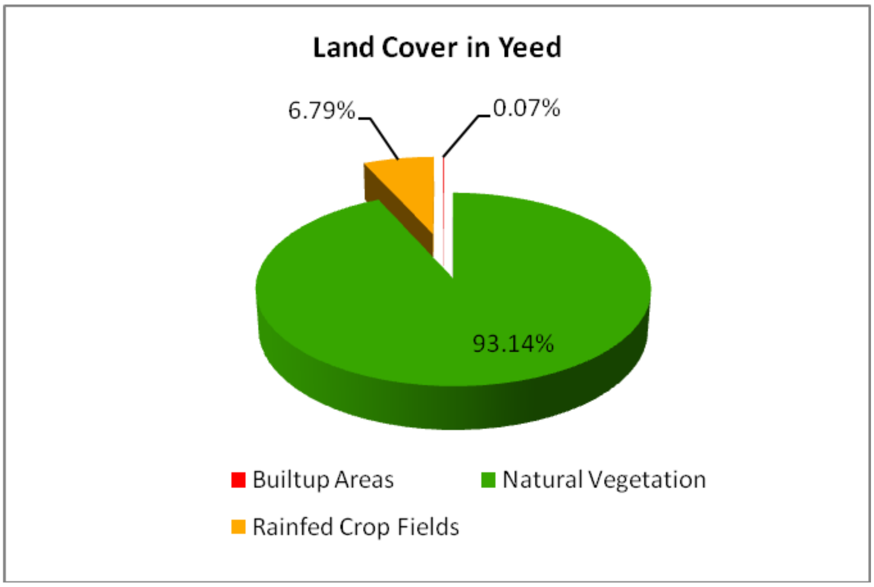
Land Cover in Xudur District	No of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Bare Areas	3	0.01	74	1
Builtup Areas	14	0.06	346	3
Natural Vegetation	19515	88.95	482922	4829
Rainfed Crop Fields	2408	10.98	59589	596
Total	21940	100.00	542931	5429



36. YEED DISTRICT

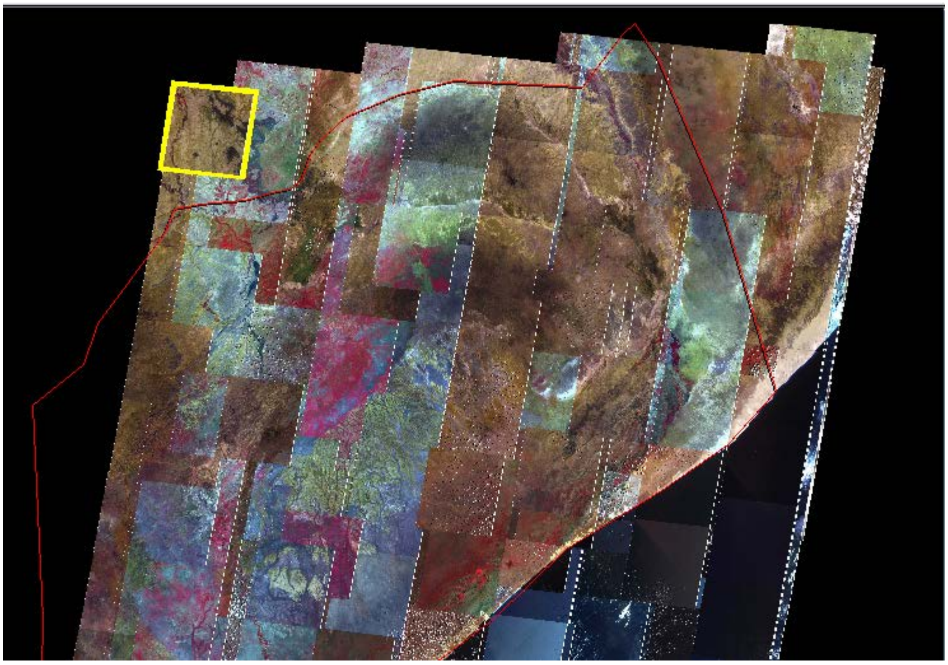


Land Cover in Yeed District	No of Dots	Percentage (%)	Area (Ha)	Area (sq.km)
Builtup Areas	9	0.07	227	2
Natural Vegetation	12231	93.14	308291	3083
Rainfed Crop Fields	892	6.79	22483	225
Total	13132	100.00	331001	3310



Annex 2:

ASTER image coverage of the study area



Annex 3:

ASTER satellite image index