

***Research Agreement Between
The Research Institute for Humanity and Nature
And
Çukurova University***



***DESIGNING LOCAL FRAMEWORKS FOR
INTEGRATED WATER RESOURCE MANAGEMENT***



**Çukurova University Research Group
SEYHAN BASIN CASE SITE
REPORT**

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ADANA

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WORK TASK-1. Hydrological modeling for Seyhan River

The main objective of this research is to estimate the effects of hydrological quantities (runoff - evapotranspiration) on the forest productivity of Seyhan River Basin located on the Taurus Mountain of Eastern Mediterranean coast of Turkey.

The region covers an area of approximately 21.45 km² and comprises pure and mixed conifer forests. These forests are classified as a Mediterranean evergreen cover type (Köppen, 1931) and estimated to be approximately 100 years old from tree cores. Dominant tree species are Crimean pine (*Pinus nigra*), Lebanese cedar (*Cedrus libani*), Taurus fir (*Abies cilicica*), Turkish pine (*Pinus brutia*), and juniper (*Juniperus excelsa*) (Davis, 1965). The prevailing climate is Mediterranean characterized by mild and rainy winters and hot and dry summers. The total annual rainfall is approximately 800 mm. Rainfall is variable in amount and timing in that 75% of rain falls mainly during autumn and winter. The mean annual temperature between 1990 and 2002 was 19 C, with mean minimum and maximum temperatures of 8 C in January and 30 C in July, respectively. Predicting and modelling the interactions of water cycles of this region are an important issues to understand future dynamics of forest ecosystems under different scenarios. This has particular importance in managing water resources at semi-arid environments of Mediterranean.

Modelling Hydrological Quantities

The main objective of the hydrological modelling part of this study was to provide robust and reliable estimates of spatially distributed long-term hydrological quantities for the Eastern Mediterranean. The impact of projected climate change on the long-term hydrological balance and seasonal variability were assessed and analysed by using a conceptual hydrological model. The conceptual hydrological model J2000 developed by Dept.of Geoinformatics, Friedrich-Schiller University, Germany (Peter Krause and Sven Kralisch) was used to provide spatially distributed long-term estimates of the hydrological quantities including, actual evapotranspiration, runoff generation, and groundwater dynamics.

The spatially distributed J2000 model (Krause, 2001, 2002) was adapted from the JAMS modelling framework system (Kralisch and Krause, 2006). The quantification process of the J2000 model was based on time series of precipitation and other climate elements, along with spatially distributed information about topography, land-use, soil types and hydrogeology. Since JAMS/J2000 requires spatially distributed modelling entities, the 'Hydrological Response Units' (HRU) concept (Flügel, 1995) was adapted for this study. Criteria that are used for defining homogeneity are based on the hydrological system analysis of the basin. HRUs are delineated by overlaying land cover, soils, geology and topographic parameters which were identified as being the driving forces of hydrological process dynamics (Flügel, 1995). Therewith, each HRU is characterized by a set of parameters representing the conceptual storages and runoff generation dynamics. To reduce the number of HRUs, the input layers were reclassified with regard to their hydrological relevance. Standard ArcGIS 9.2 (ESRI, 2008) geoprocessing tools and customized scripts for deriving HRU flow connectivity were used for HRU delineation. Overlaying the input layers, HRU maps were derived for each basin. To reduce the overall number of spatial HRU entities, the resulting unique HRUs were then aggregated to polygons larger than 0.5 ha with respect to their

hydrological relevance and neighbourhood proximity. Eventually, approximately 15 000 hydro-modelling units were delineated for the entire Seyhan Basin.

J2000 also requires meteorological inputs (precipitation; minimum, average and maximum temperature; sunshine duration; wind speed and relative humidity) from the closest observation stations. In this study, daily hydrometeorological data were used for the systems analysis and modelling after a comprehensive pre-processing including the check and statistically correction of the data. Also, the temperature data were analysed to eliminate effects caused by cold air pooling and other mountain related local climate effects. After preprocessing, the times series were converted into model input files. In the model, all point information is transferred to an individual model unit with the regionalisation approach of J2000, which takes horizontal and vertical variability of the climate data into account. The regionalised information is then used for simulating the hydrological processes as shown in Figure 4.

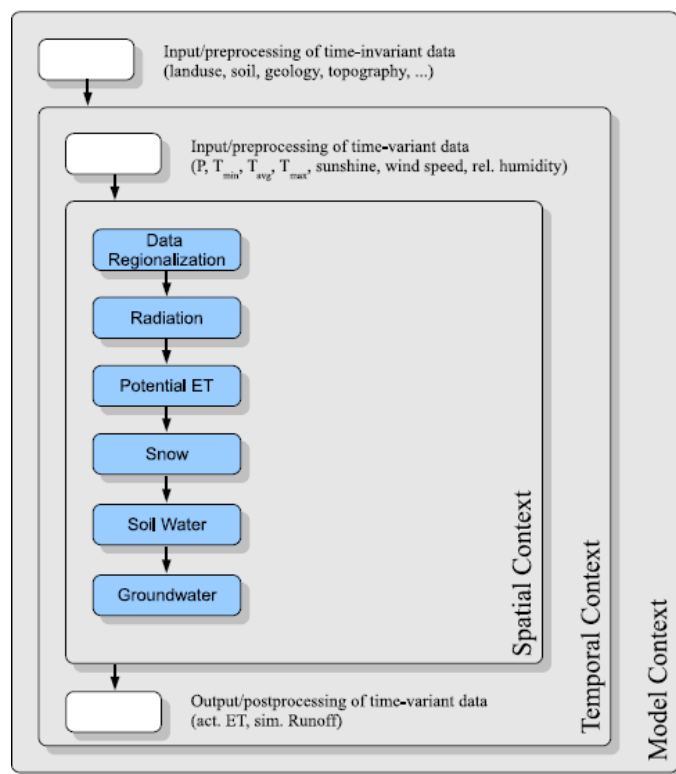


Figure 4. Simplified illustration of the J2000 layout

The estimated hydrological quantities will be computed for past, recent and future conditions to provide a basis for the analysis of the potential long-term impact resulting from changing climate conditions. Figure 5 shows the workflow applied to provide the information required for the hydrological modelling.

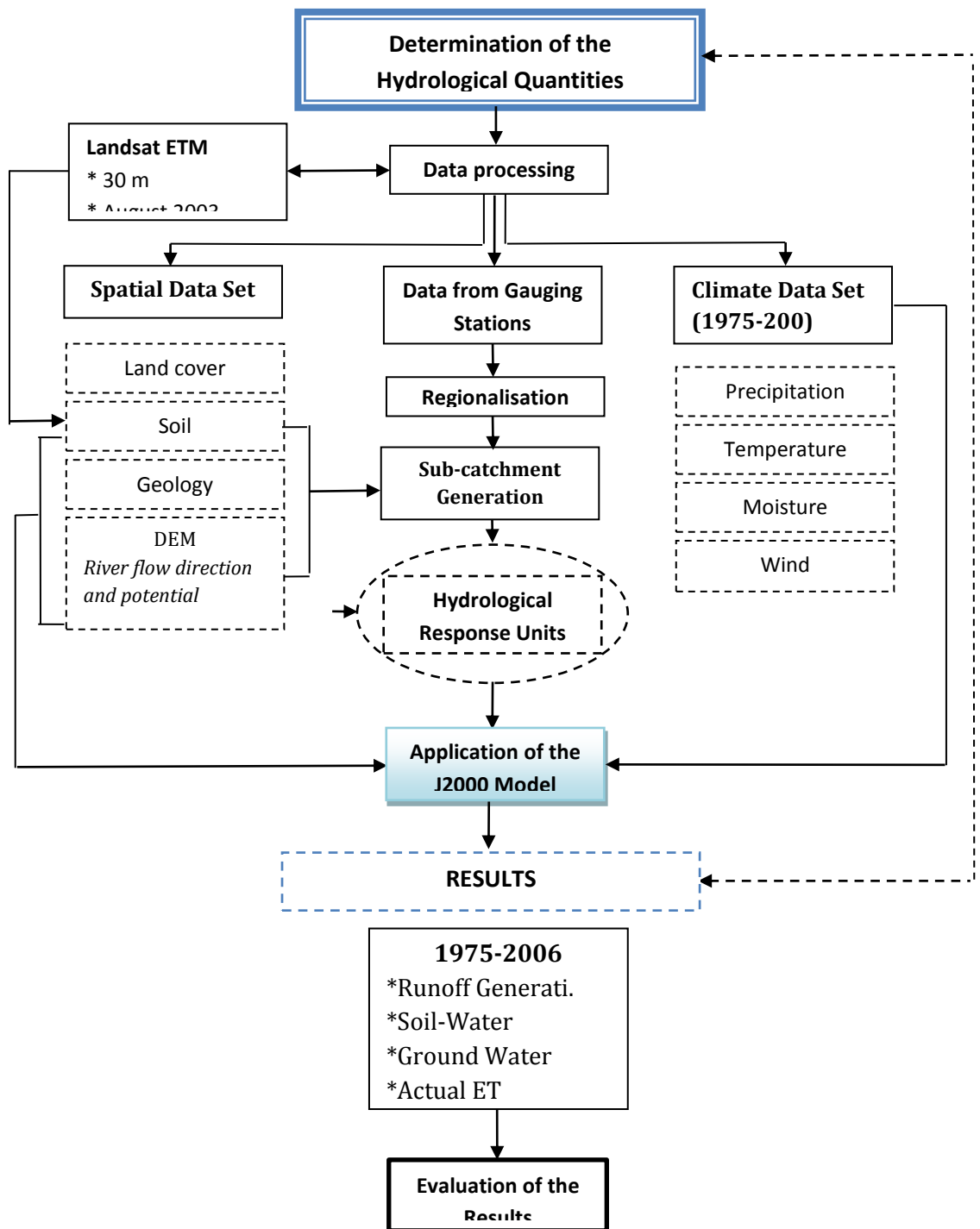


Figure 5. Flow Diagram of the Hydrological Modelling Part of the research.

The spatial and downscaled meteorological time series will be used to compute the spatially distributed hydrological quantities such as precipitation, evapotranspiration and runoff generation with a conceptual hydrological model approach J2000.

Hydrological Modelling Results

The achieved results show the current climate conditions in Seyhan Basin The mean annual precipitation and temperature rates for 1975-2006 period were given in Figure 6 and 7.

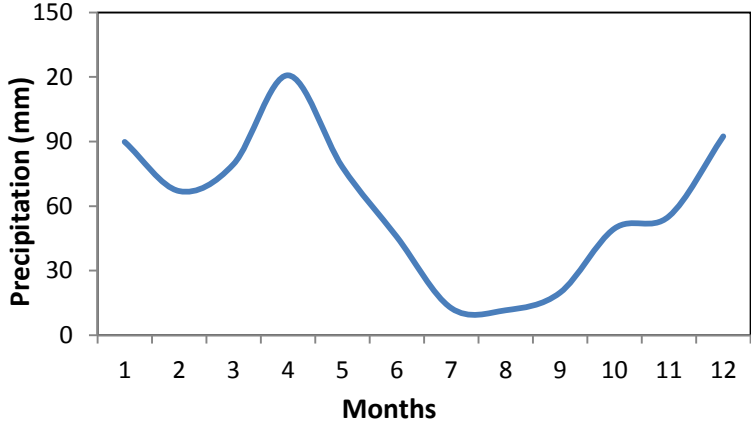


Figure 6. The mean annual precipitation of the Seyhan Basin (1975-2006).

Precipitation is the most important factor for hydrology. The results showed that a strong decrease occurred in summer season. An increase was observed for precipitation of the basin, in fall.

ET (Figure 8) ws estimated as a function of precipitation and temperature, respectively. The simulation results indicated an increase of ET for summer.

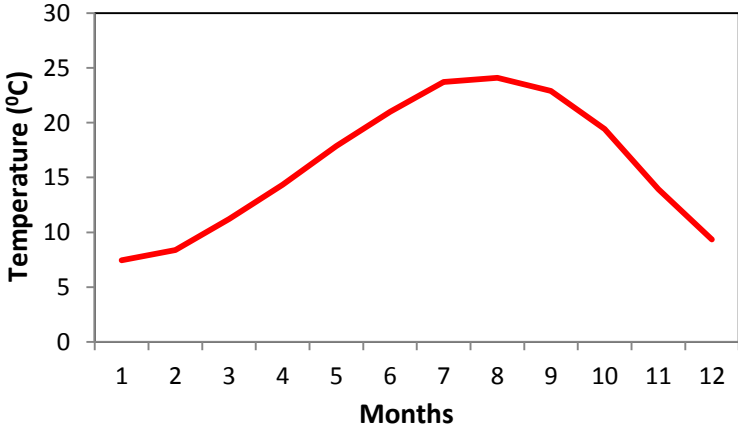


Figure 7. The mean annual temperature of the Seyhan Basin (1975-2006).

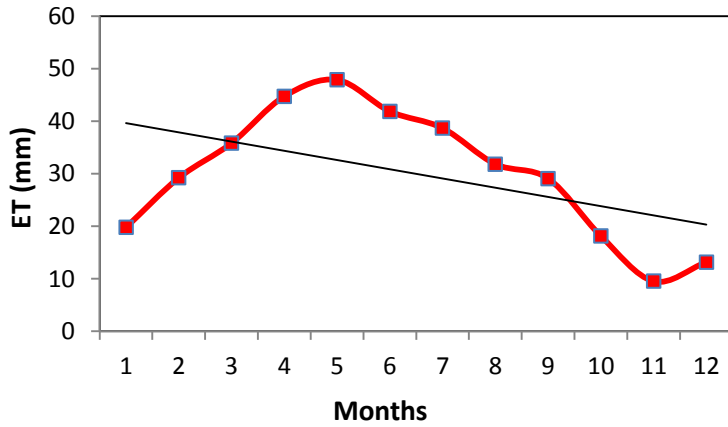


Figure 8. The mean annual ET of the Seyhan Basin (1975-2006).

Runoff generation is computed by the J2000 as the result of precipitation, evapotranspiration and potential changes in the snowpack as well as the two storages for soil moisture and groundwater. The mean annual runoff generation is given in Figure 9.

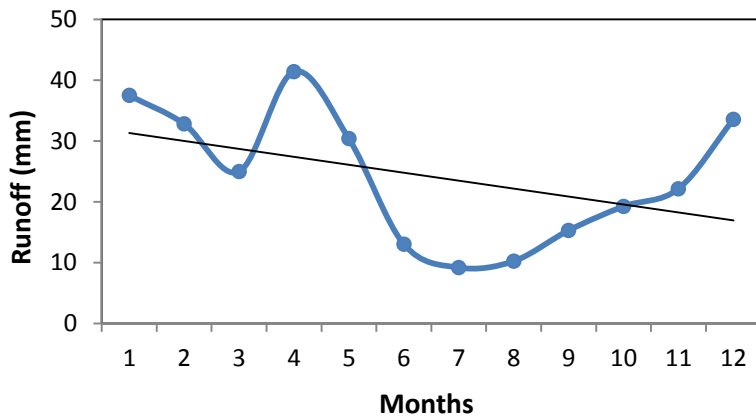


Figure 9. The mean annual runoff generation of the Seyhan Basin (1975-2006).

Present runoff generation was mapped at a 90 m grid cell size (Figure 10).

For spatially averaged and total annual runoff generation was estimated as 297.13 mm. In spring, an increase was computed as a result of snow melting in the higher areas.

The amount of the hydrological quantities are given in Table 1.

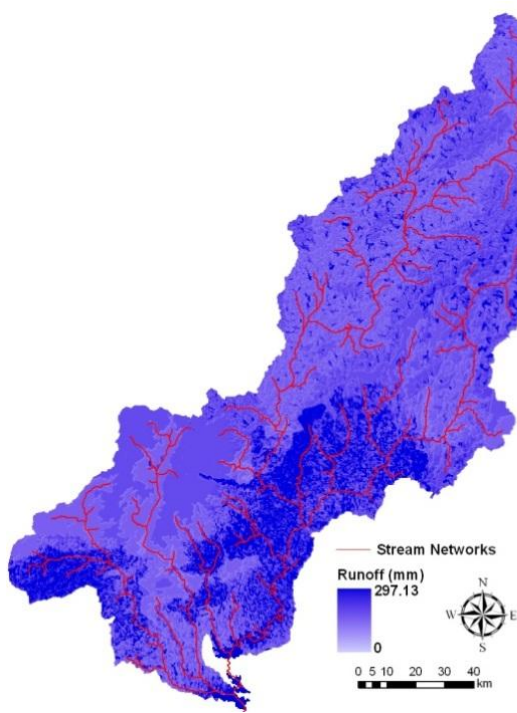


Figure 10. Present runoff generation map of the Seyhan Basin.

Table 1. The hydrological quantities of the Seyhan Basin

Hydrological Quantities	1975-2006
Precipitation (mm)	721.95
ET	355.10
Runoff	289.57
GW (Upper Zone)	53.68
GW (Lower Zone)	31.69
Soil-Water (Middle Pore Storage)	62.06
Soil-Water (Large Pore Storage)	51.42
Interception	60.92

The total annual ET was estimated as 355.1 mm. The general ratios of runoff, ET and GW dynamics are given in figure 11.

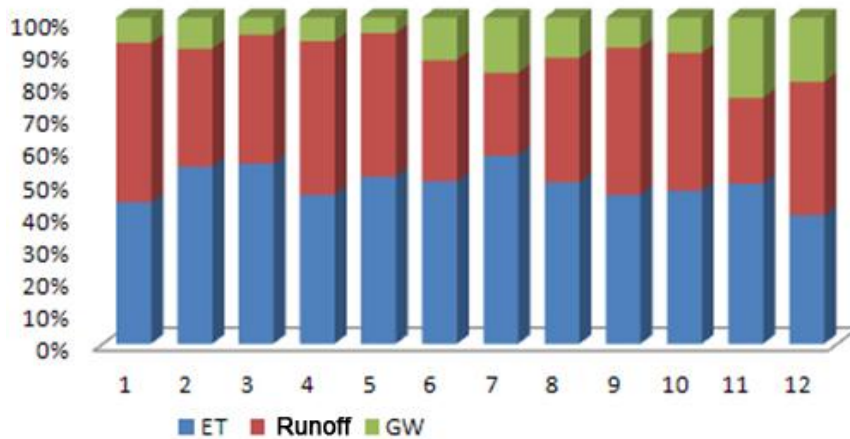


Figure 11. The rates of the hydrological quantities of the Seyhan Basin.

Within this research, the impact of projected climate change on snow dynamics was analysed and estimated. The snow module which is a sub-module in J2000 modelling system was used to estimate snow melt, snow accumulation and snow-water equivalent (SWE) for the Seyhan Basin. The predicted snow dynamics for present is shown in Figure 12, 13, 14.

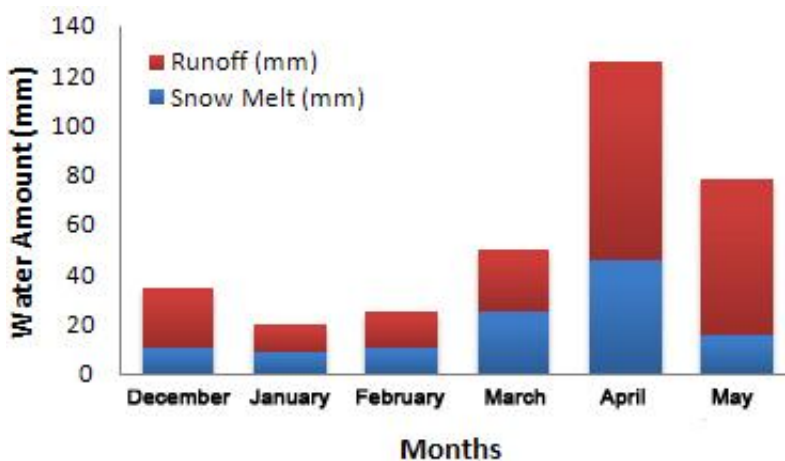


Figure 12. Snow melt – runoff ratio distribution of the Seyhan Basin (*present-1975-2006*).

The snow melt potential constitutes 37% of whole runoff generation in the Seyhan Basin. The total mean snow melt-runoff was computed as 142.5 mm per year

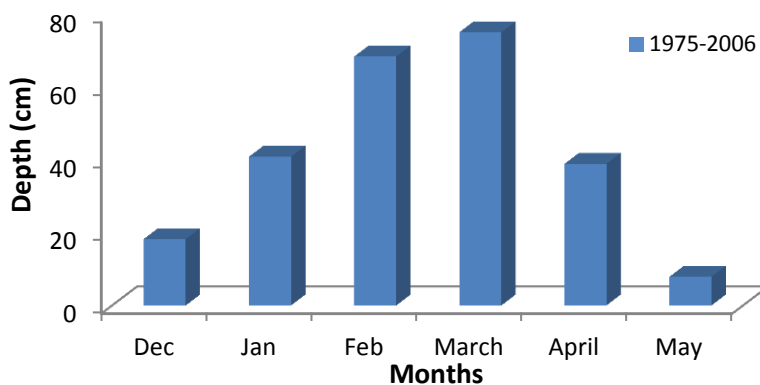


Figure 13. Distribution of snow depth in the Seyhan Basin.

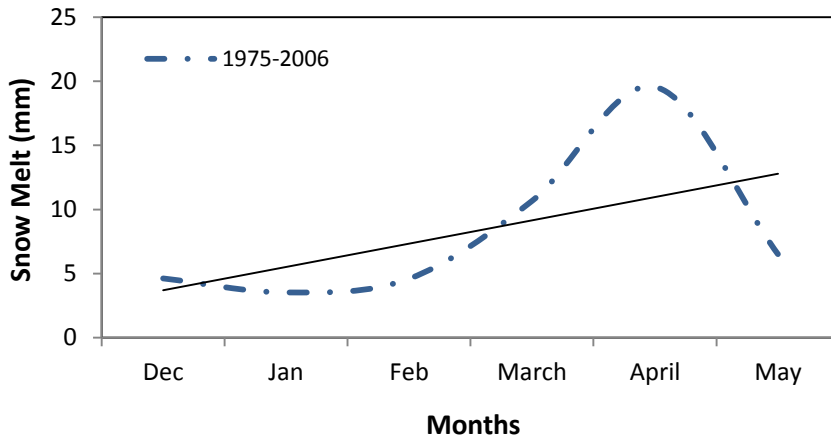


Figure 14. Snow melt distribution in the Seyhan Basin.

The snow melt runoff potential is very different in the study area. This potential increases from February till April.

The water balance (Figure 15) was computed by J2000 as the result of the hydrological quantities including runoff generation, snow dynamics, ET, GW and soil-water components.

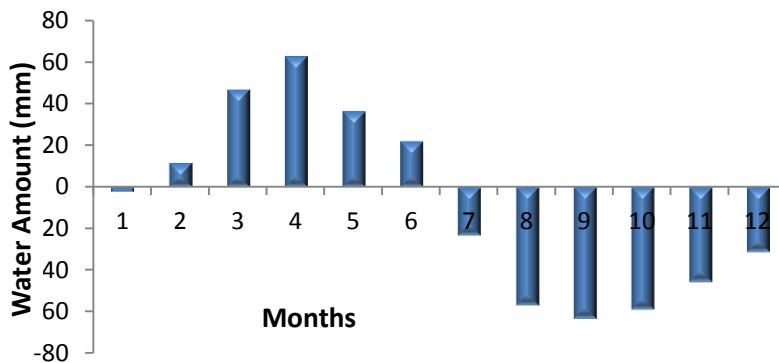


Figure 15. Water balance of the Seyhan Basin.

Total amounts of the hydrological quantities were also estimated for the Seyhan Basin (Table 2). The precipitation was estimated 13.6 km^3 in the study area. The total amount of precipitation was estimated as 501 km^3 in Turkey. This result showed that Seyhan Basin is not rich in terms of precipitation distribution in Turkey. The total ET was estimated as 6.70 km^3 .

Table 2. Total amounts of the hydrological quantities.

Hydrological Quantities	Water Amount (km^3)	
	1975-2006	Turkey (total)
Precipitation	13.6	501
ET	6.70	274
Runoff	5.47	186
Ground Water	1.61	41

Soil-Water	2.14	Not derived
Interception	0.25	Not derived

The predicted temperature increase due to climate change will have impact on other climatological, meteorological and hydrological processes. Additionally, the projected precipitation change would result in more rainfall during the winter months and less precipitation during summer and fall. The increase of the temperature and the decrease of precipitation will have impact on the regional water budget in and around the study area. It can be concluded that, the general water budget will increase in winter months and decrease in summer months.

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WORK TASK-2. Akarsu Monitoring

The Project area in Turkey is located in Lower Seyhan Plain (LSP), named after the River Seyhan, in the eastern part of the Mediterranean region, Adana, Turkey. The LSP covers a gross area of 213 200 hectares of land, of which 174 088 ha are suitable for irrigation. The actually irrigated area has progressively increased since 1960 to reach 137 299 ha, out of 153 277 ha, in 2007. The LSP mainly consists of two plains, viz. Yuregir Plain (133 200 ha) and Tarsus Plain (80 000 ha). The Seyhan River, with an annual flow of 6.3 km³, supplies water for irrigation of excellent quality (EC < 0.35 dS/m). An area of 40 657 ha, located in the southern part of LSP (*the LSP Forth Stage Project Area- LSP IV. SPA*) has presently no irrigation facilities, but it is planned to be irrigated in the future. Low soil permeability is the main constraint to irrigation. The study area, Akarsu Irrigation District (AID), is located between 36° 57' 32" and 36° 50' 43" N latitudes and 35° 40' 22" and 35° 28' 42" E longitudes. It is in south-east of Adana and west part of the Ceyhan River (Figure 16).

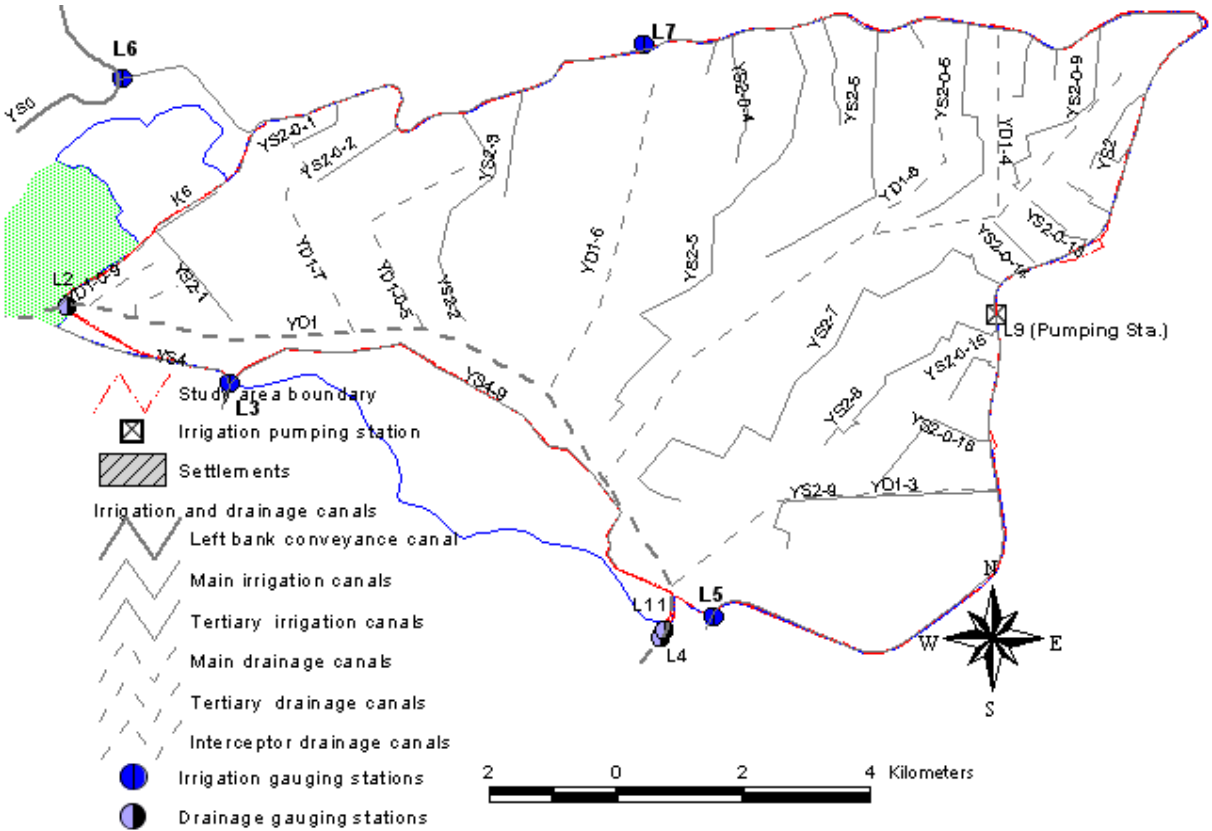


Figure 16. The layout of main and secondary irrigation and drainage canals in the Akarsu Irrigation District (AID).

Mass Balance Works

Determination of Irrigation and Drainage Flows: In order to carry out the mass balance studies for water and salt, it is necessary to measure or estimate the main inputs and outputs in the Akarsu ID. In terms of water balance, the primary inputs were considered as **Precipitation (P)**, **Irrigation inflows (I_{in})**, **drainage inflows (Q_{in})** incoming from outside areas, and outputs are **crop EvapoTranspiration (ET_c)**, **Irrigation outflows (I_{out})** discharging from YS2 main irrigation canal, **drainage outflows (Q_{out})** at the outlet of Akarsu ID. In Akarsu, the inputs and outputs for water balance are measured at the gauging stations installed at the critical points shown in Figure 16. In this research, as seen in Figure 16, three irrigation-inflow sites (L3, L6

& L7) and one irrigation-outflow site (L5) were selected. Near Abdioglu village, there is a pumping station with $3\,240\text{ m}^3\text{ h}^{-1}$ capacity to supply additional irrigation water during the peak irrigation season when the main irrigation canal (YS2) fails to meet farmers' demand. Therefore, an additional irrigation gauging station (L9) was set up to monitor supplied water through the pumping (Figure 16). There are three drainage-gauging stations (L2, L11 & L4) in the district. **L2** and **L11** are for drainage inflow measurements and L4 for drainage outflow measurements (Figure 16). In the reporting period, limnigraphs were set up such that flow depths in the canal cross sections considered were recorded on hourly base by averaging 6 readings with ten minutes intervals in an hour. The hydrological data processing have continued, and the results will be given in the next activity report.

Salinity Observations in Drainage and Irrigation Waters: In order to carry out salt balance work in Akarsu District, salt concentrations of inflows and outflows were measured in the period. To this aim, water samples from L2, L6, L9 and L11 were taken biweekly. However, an automatic water sampler was installed on L4 and water samples were collected on daily base. All the water samples were taken to the Laboratory to perform chemical analysis on the samples. The chemical analysis of water samples included electrical conductivity (EC), pH, SAR and concentrations of “*selected anions and cations*” (Na, Ca, Mg, K, HCO_3 , CO_3 , SO_4 and Cl). Total dissolved salts (TDS, mg L^{-1}) of irrigation and drainage in- and out-flows were calculated by summing up the concentrations (mg L^{-1}) of “*selected anions and cations*”. Laboratory analysis of water samples and mass balance calculations need some time to finalize. For this reason, the results will be given later.

3. Spatial Distribution of Shallow Groundwater (GW) Dept and Salinity

In Akarsu ID, total of drainage observation wells –up to 3 meters depth- is 108 (Figure 17). In order to determine spatial distribution patterns of GW depth and quality, i.e. salinity, *depths to groundwater table* were measured in the drainage observation wells in January (wet period), April (before irrigation season), July (peak irrigation season) and at the end of September (end of irrigation season, concurrently with collection of GW samples for salinity determinations in the lab.

4. PRELIMINARY RESULTS

Groundwater depth measurement and salinity data were processed in geographic information systems media, and maps for GW depth and salinity (EC , dS m^{-1}) were generated for “*rainy*”, “*before irrigation season*” and “*peak irrigation season*” periods.

Descriptive statistics of observed data

Although the number of existing drainage observations wells is 108 in the District, the GW depth and salinity measurements were realized in less drainage observation wells (Table 1) due to the accessibility problems and impermanency of observation holes. For the most part, farmers inadvertently damage drainage observation wells during agricultural activities in the field.

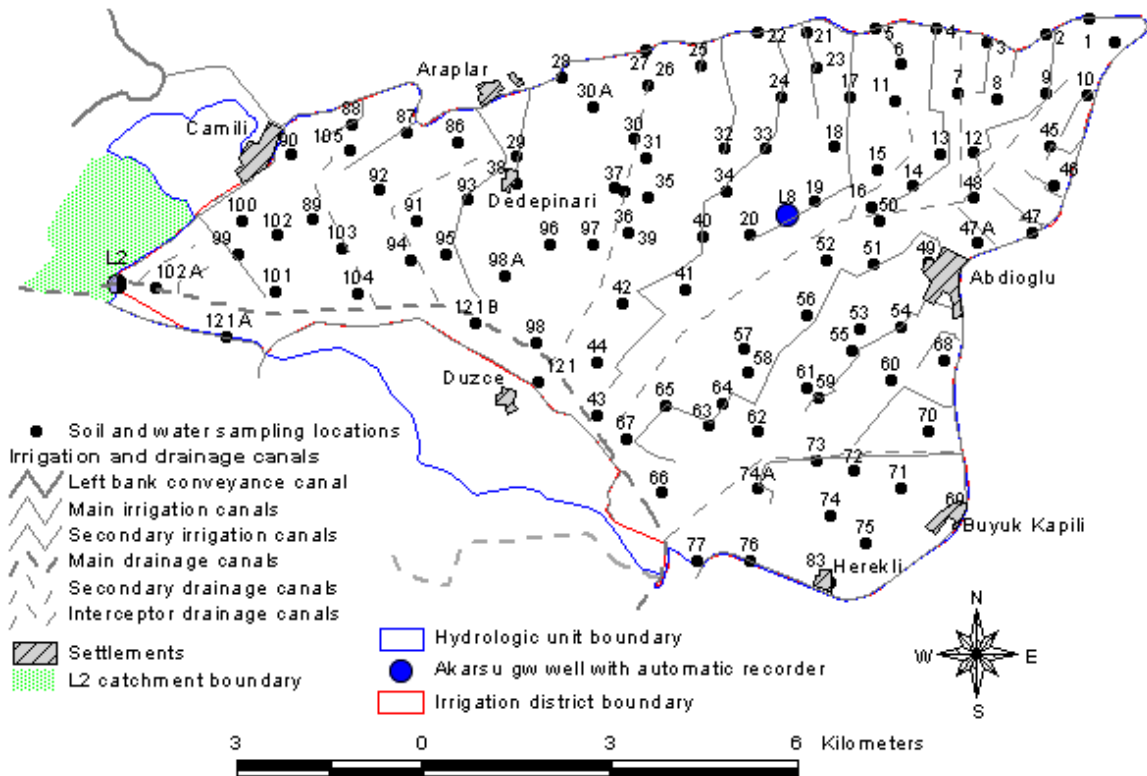


Figure 17. Distribution of drainage observation wells in Akarsu.

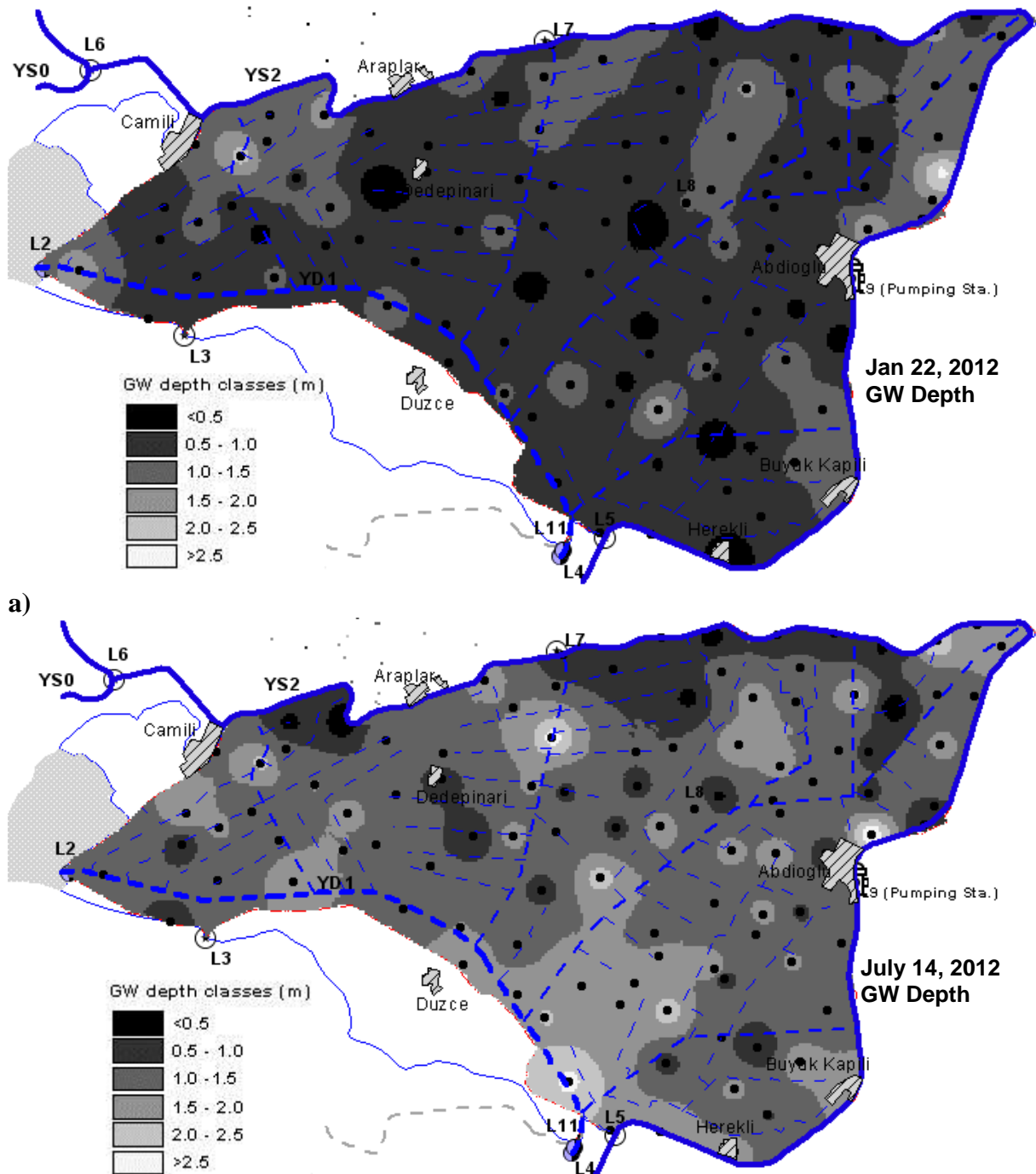
Table 3. Some descriptive statistics of groundwater depth and salinity

Hydrological Year	GW depth (m)			GW salinity (dS/m)		
	Jan 22	Apr 21	July 14	Jan 22	Apr 21	July 14
2012						
Mean	0.91	1.45	1.3	2.0	2.6	2.7
Standard Error	0.05	0.05	0.1	0.3	0.4	0.4
Median	0.83	1.46	1.4	1.1	1.3	1.3
Standard Deviation	0.47	0.47	0.6	2.7	3.6	3.5
Sample Variance	0.22	0.23	0.3	7.5	12.7	12.3
Standardized Kurtosis	0.91	0.97	-0.4	10.2	8.7	6.9
Skewness	0.82	0.47	0.1	3.1	2.9	2.6
Range	2.60	2.67	2.7	14.5	18.4	18.7
Minimum	0.00	0.50	0.1	0.3	0.4	0.4
Maximum	2.60	3.17	2.8	14.8	18.9	19.1
Number of observations	98	102	99.0	95.0	91.0	97.0
Confidence Level(95.0%)	0.09	0.09	0.1	0.6	0.7	0.7
CV (%)	52.3	32.8	43.7	134.3	137.3	129.3

Mean GW dept is found the smallest in the rainy season indicating that rainfall is the main source of high GW table in the district. Before irrigation season, GW table goes down to some extent and starts to rise again in the course of irrigation season. In terms of GW salinity, EC is the lowest in the wet period due to the dilution effects of winter rains in the region. However, although excess irrigation water usage is used in this period, mean EC value increases to 2.7 dS m^{-1} in the peak irrigation season due to the evapotranspiration concentration factor of irrigated agriculture. The variability in GW depth is low (CV=33-52%) compared with the variability GW salinity.

Spatial distribution of groundwater depths

GW maps produced in GIS media showed that 72% of study area has GW depth less than 1 m in winter time. Additionally, areas having GW depths between 1.0 and 1.5 m covered 26% of the District in the rainy season. Severe drainage problem areas (GW<1.0 m) prevailed almost everywhere in the command area (Figure 18). However, severe drainage problem areas covered only 4% and 14% of the District in April (start irrigation season) and July (peak irrigation season, respectively). It is important to highlight that 96% of area has a GW depth >1.0 m at the start of irrigation season and appeared again in the irrigation season.



b) Figure 18. Spatial distribution patterns of groundwater depths: (a) In rainy season, (b) In peak irrigation season

Hypsometric GW depth curves were developed through using the zonal statistics of GIS software and presented in figure19. It can be concluded from these curves that April (start of irrigation season) is the safest period in terms of drainage problems in the region. Start of irrigation caused to rise GW table in the area indicating the use of excess irrigation water in irrigation.

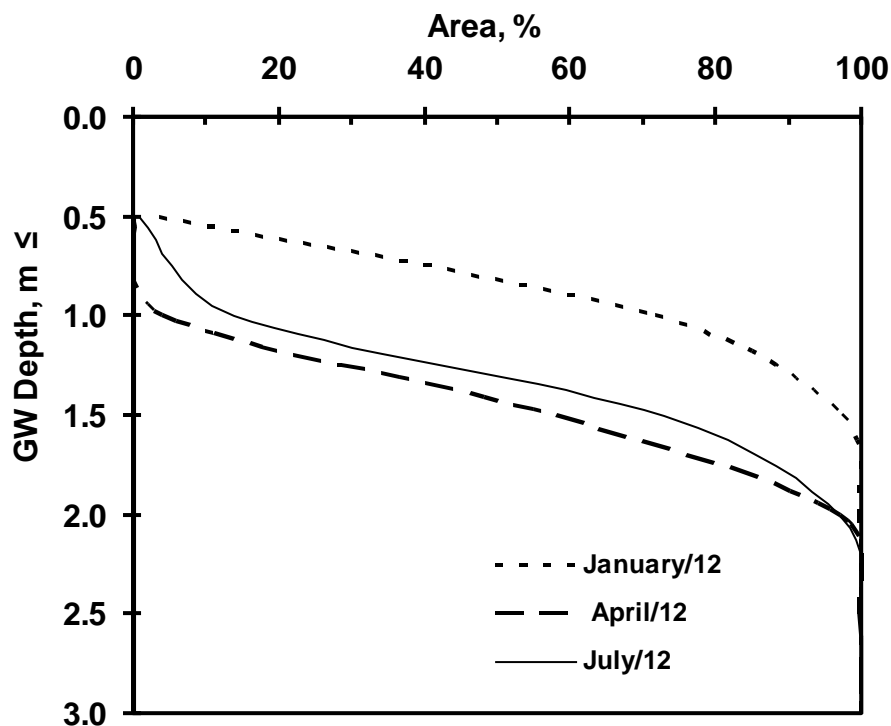


Figure 19. Hypsometric groundwater depth curves for the periods considered

Spatial distribution of groundwater salinity

Groundwater salinity maps produced in GIS media showed that Akarsu ID have no severe GW salinity problems (Figure 20). No area has salinity $>30 \text{ dS m}^{-1}$. Although the spatial variability is rather high ($\text{CV} > 125\%$ in Table 1), areas having GW salinity problems ($\text{EC} > 5 \text{ dS m}^{-1}$) have provided more or less the same consistency in the observation period. In July, GW salinity along the main irrigation canal decreases to some extent indicating that seepage from main irrigation canal is continuously recharging GW body during irrigation season.

Hypsometric GW salinity curves (Figure 21) proves that areas having severe GW salinity problem ($\text{EC} > 5 \text{ dS m}^{-1}$) are consistent, and areal coverages varies from 5% (in rainy season) to 11% (in peak irrigation season). As seen from Figure 6, areas of GW $\text{EC} > 5 \text{ dS m}^{-1}$ is about 10%.

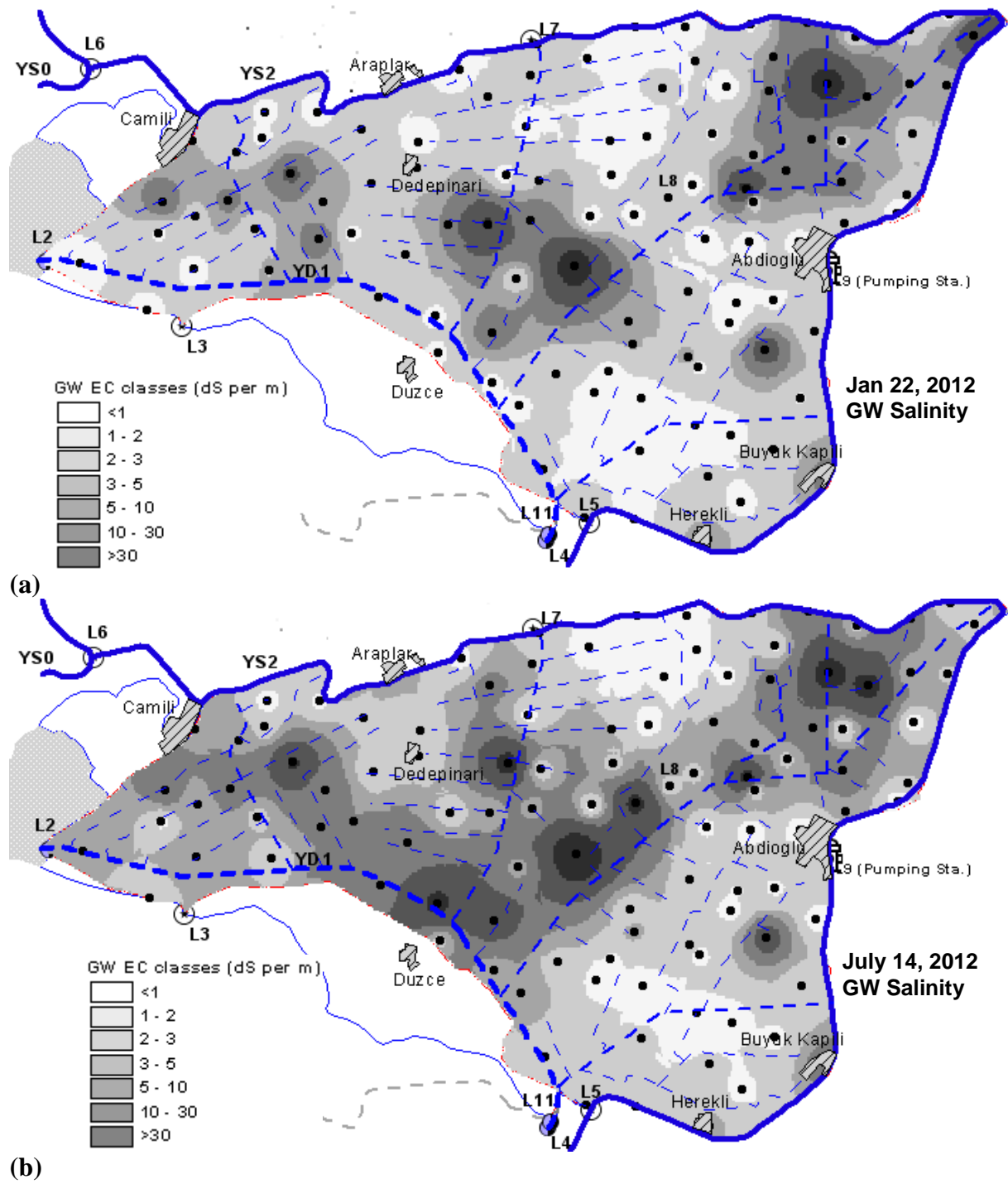


Figure 20. Spatial distribution patterns of groundwater salinity (EC, $dS m^{-1}$): (a) In rainy season, (b) In peak irrigation season

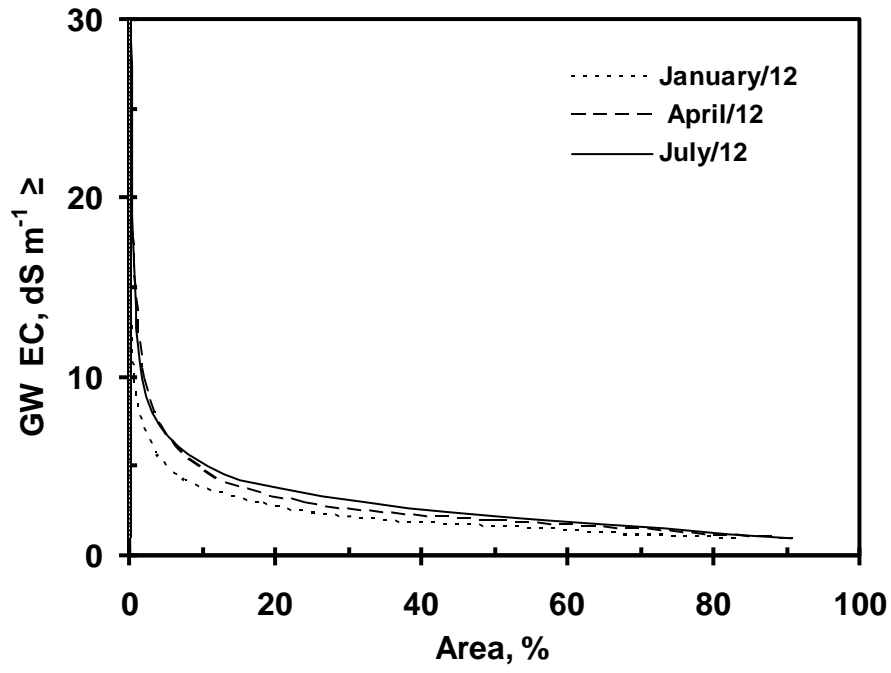


Figure 21. Hypsometric groundwater salinity curves for the periods considered

WORK TASK-3. Salinity monitoring in Cukurova Plain

Salinity works has been terminated due to CHRIS-Proba failure from March 2012. Fortunately, this technical problem was solved in October 2012 and the new acquisition was scheduled for 14 and 15 October 2012 over Akarsu and Yemişli test sites. The results will be presented at the second interim report. Landsat TM/ETM data was used to cover this period. However, the potential of Landsat TM/ETM data potential in salinity estimation was well below the CHRIS-Proba sensor data due to the bandwidth. On the other hand, the effects of salinity on crop (wheat) productivity were estimated and mapped successfully by Landsat TM/ETM dataset and the results were presented in Land use/cover investigation (Work Task 4) section.

Additionally, soil salinity was estimated applying a NDVI based equation using 23th August 2011 Landsat TM data. Previous works showed that the best fit detected between soil salinity and NDVI was R^2 0.70. However, detection of high and low saline areas accurately in cotton areas was failed.

$$EC_e = 1.68 * NDVI^{(-1.18)} \quad (1)$$

This index worked with only saline cotton areas using NDVI. Therefore, firstly NDVI based index applied to all images and cotton fields were extracted (Figures 22, 23).

According to results this index not reliable in parcel scale, however overall trend in LSP may be detected using this technique. Mean value of all region was defined as $EC_e = 2.01$. This value is confirmed by previous work results (Satir et al., 2010).

Reference

Onur Satir, Suha Berberoglu, Selim Kapur, Takanori Nagano, M. Akif Erdogan, Cenk Donmez, N. Yonca Satir, Erhan Akça and Kenji Tanaka 2010. Soil Salinity Mapping Using CHRIS PROBA Hyperspectral Data. ESA Hyperspectral workshop 2010 Frascati – Rome ITALY.

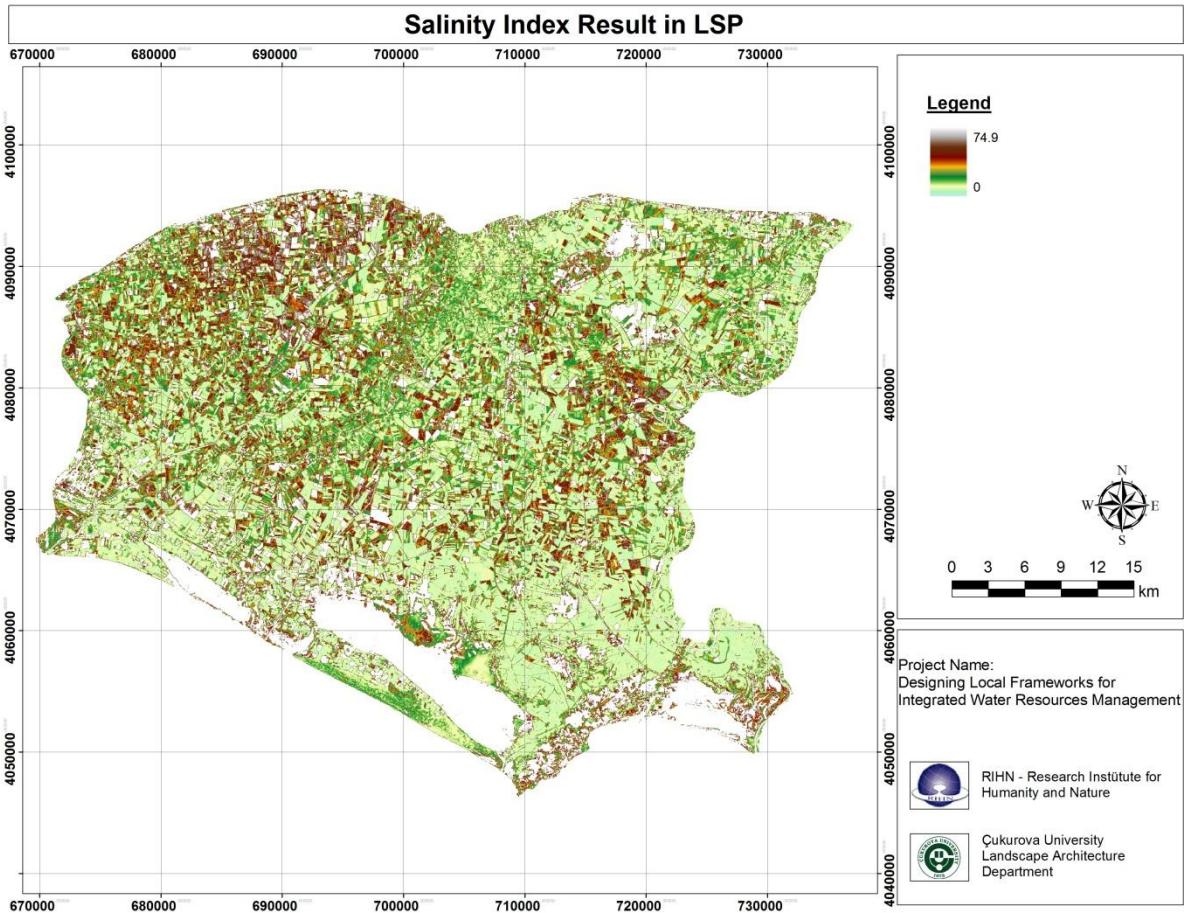


Figure 22. Soil salinity map of LSP

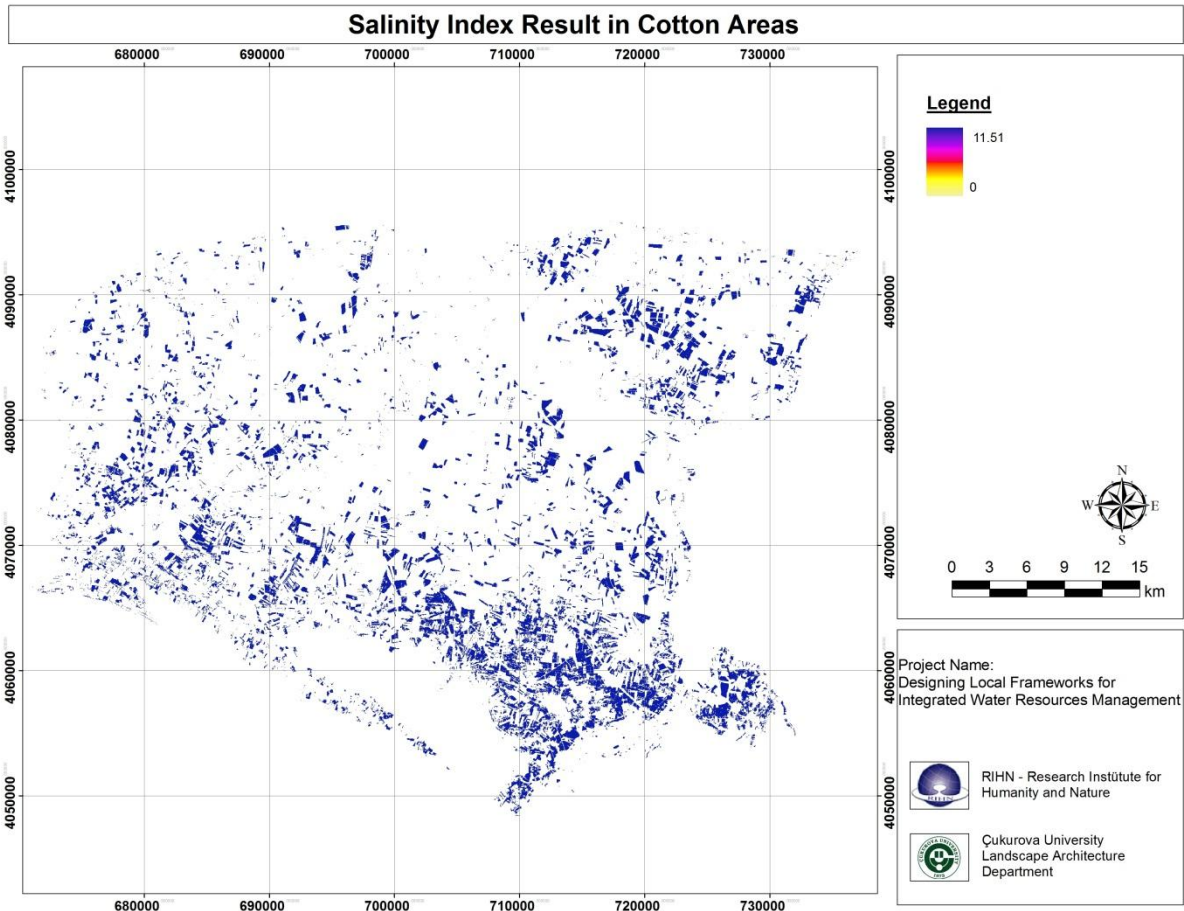


Figure 23. Soil salinity map of cotton fields in LSP.

WORK TASK-4. Land use/cover investigation

The size of the study area is about 220.000 ha. (Figure 24). Agricultural crop pattern was mapped using remote sensing techniques between 2011 and 2012. In this context, multi-temporal Landsat TM/ETM (30m spatial resolution), ASTER (15m spatial resolution) and SPOT-5 (5m spatial resolution) datasets were used (Figures 25,26,27,28). The images were cloud free. Crop pattern of LSP was mapped two times in a year covering winter and summer period as the agricultural cultivation is two or three times in a year. Major winter crops are wheat, potato, onion and lettuce whereas, summer crops are corn, cotton, soyabean, ground nut and watermelon. Additionally, citrus plantations are very important in the study area. Detailed citrus information system including, tree age, quantity, coverage, irrigation system and species distribution map was created within a project supported locally. The outcomes of this detailed citrus map was integrated to the crop pattern classification.

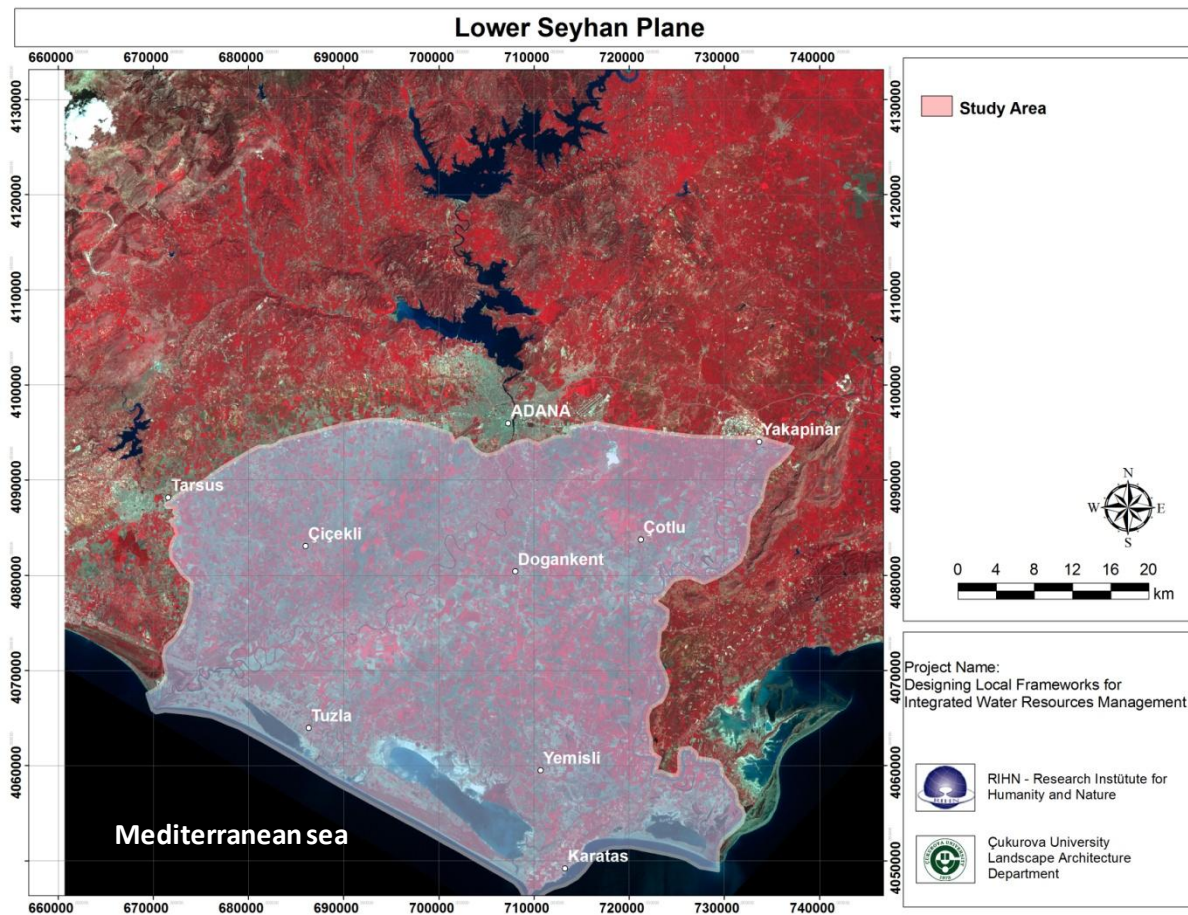


Figure 24. Lower Seyhan Plane

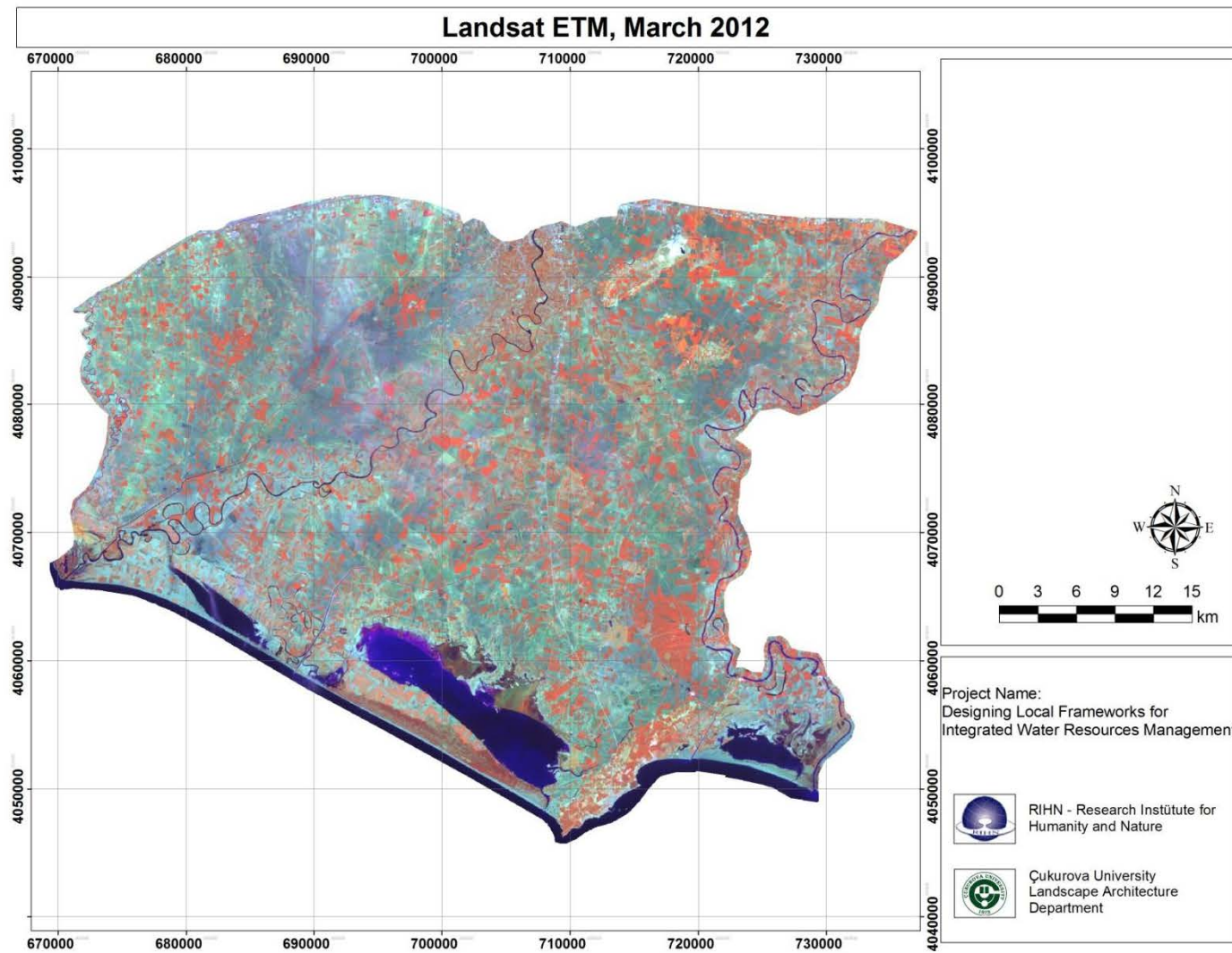


Figure 25. Landsat image recorded in March 2012

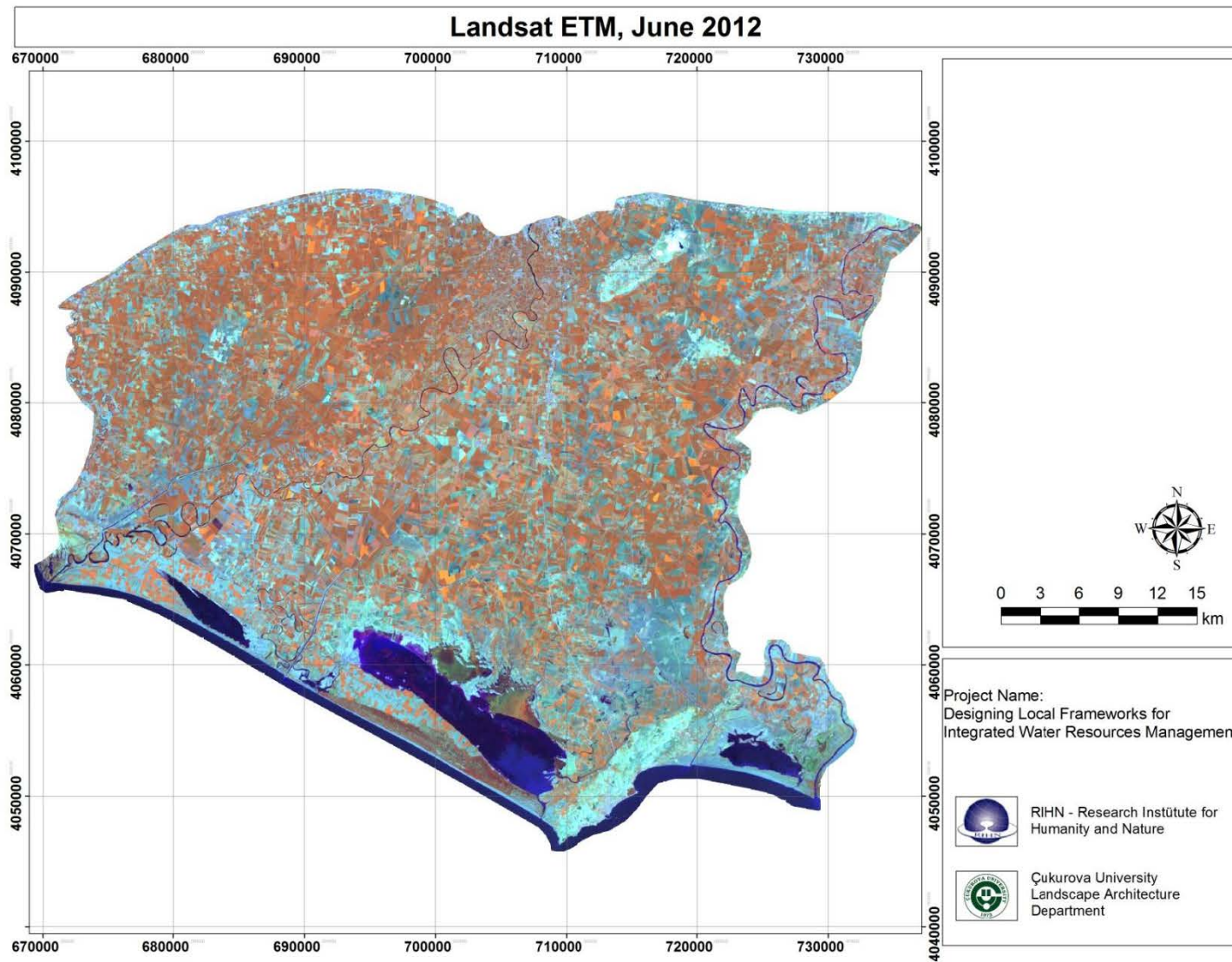


Figure 26. Landsat image recorded in June 2012

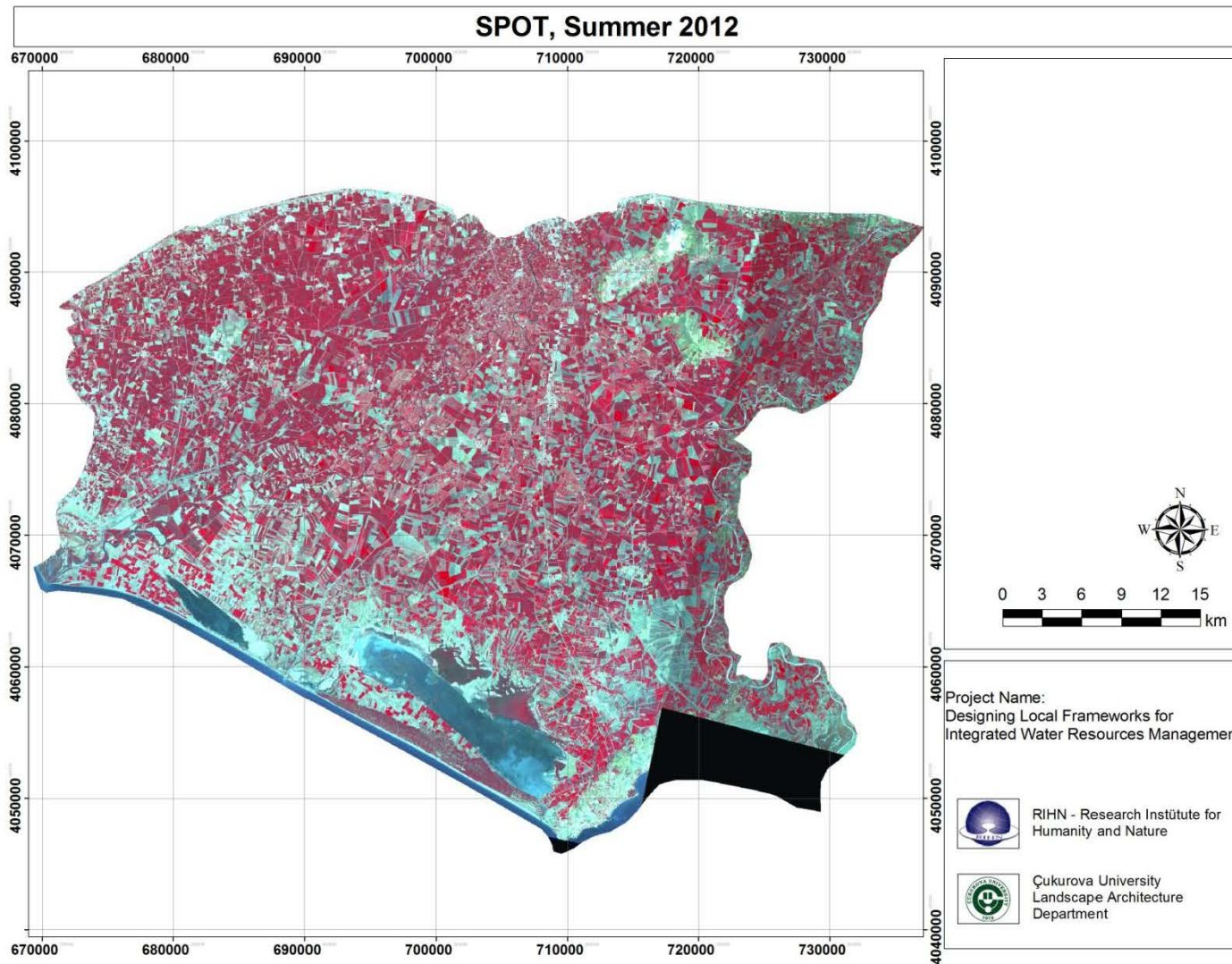


Figure 27. Spot-5 image recorded in July 2012

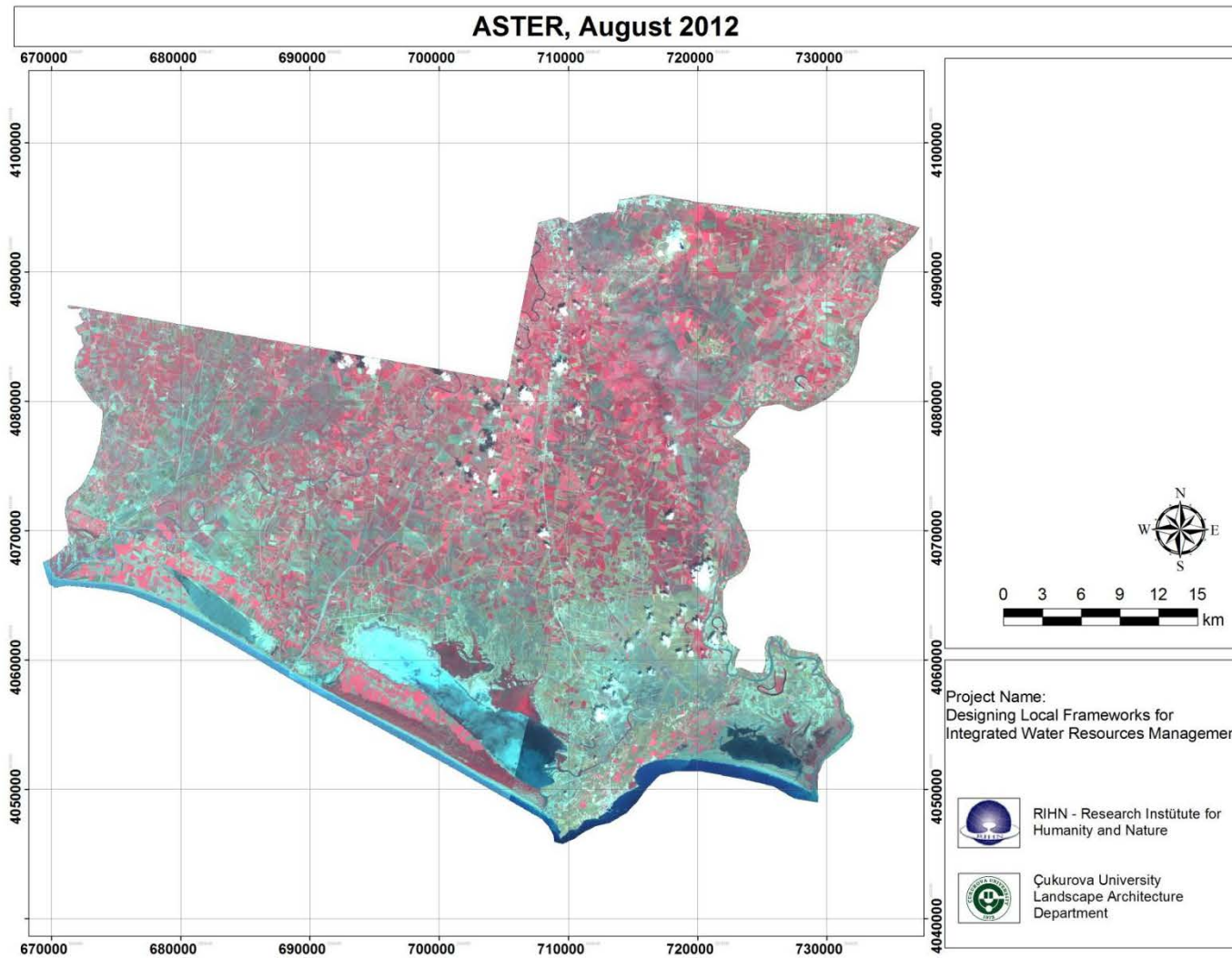


Figure 28. Aster image recorded in August 2012

Data Specifications

Three sets of data were used to map crop pattern and wheat productivity: i) remotely sensed images, ii) Land parcel data and iii) field data.

i) Landsat, Spot and Aster data sets were used for crop pattern mapping. Landsat image acquisition was terminated in 2012 particularly for summer period. The last image was recorded in June for LSP. So, ASTER and SPOT data were used to map summer crops. Spatial resolutions of the images were resampled to 30m to ensure comparability.

Landsat dataset has a large archive and potential for agricultural mapping. Only three wavebands of ASTER image were used with a 15m spatial resolution in V/NIR wavelength and pan sharpened SPOT 5 image was used in 5m spatial resolution in V/NIR (Table 4).

Table 4. Remotely sensed data specifications

Sensor	Organization	Spatial resolution	Spectral resolution	Radiometric resolution	Temporal resolution	Imaging Swath	Launch date
Landsat ETM	NASA USA	Pan: 15m MS: 30m TB: 90m	5 VNIR bands 1 SWIR bands	8 bit	16 days	185X185km	1999
ASTER	Japan&USA	VNIR: 15m SWIR: 30m TIR: 90m	1 Thermal 4 VNIR bands 6 SWIR bands 5 TIR bands (520- 11650nm)	VNIR:8 bit SWIR: 8 bit TIR: 12 bit	16 days	60X60km	1999
SPOT 5	SpotIMAGE France	Pan:2.5m VNIR:10m SWIR:20m	3 VNIR & 1 SWIR bands (490-1750)	8 bit	26 days	60X60km	2002

ii) Land parcel data was derived from 0.45m aerial photos of the LSP. Approximately 100.000 agricultural parcels were digitalized manually using ArcGIS software. This dataset was used for per-parcel classification of LSP (Figure 29).

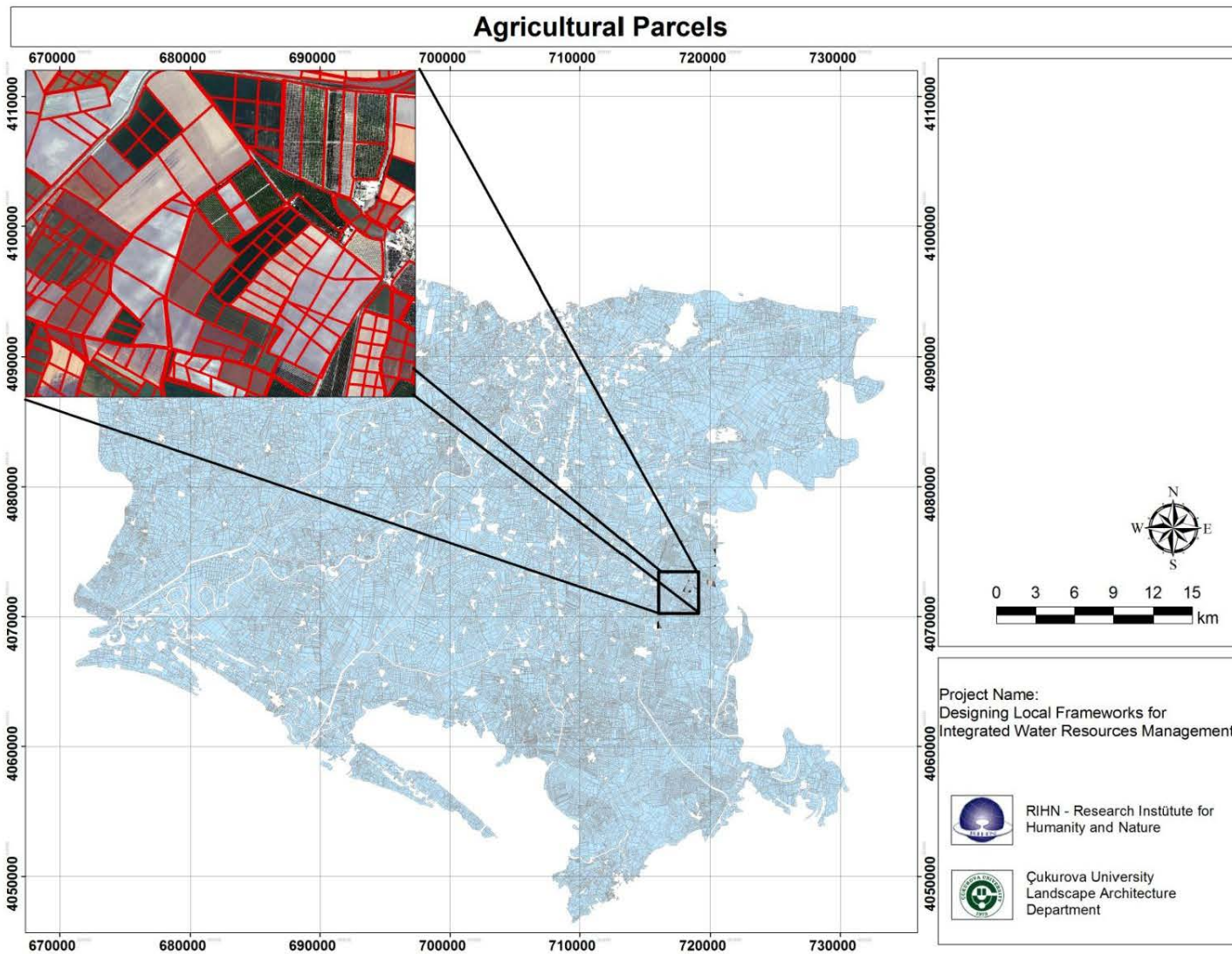


Figure 29. Digitized agricultural parcel boundary map.

iii) Field data was collected in regular field works during the crop rotation periods. Minimum 100 maximum 400 ground data was recorded in each period based on crop diversity in LSP. In addition, real time wheat yield data was collected from the trusted farmers at the end of the harvest. Minimum 30 wheat parcel were analyzed statistically to find a reliable model and to test the wheat productivity results.

METHOD

Object Based Mapping and expert knowledge system

Many Mediterranean land covers exhibit similar spectral characteristics making separation in feature space by simple per-pixel classifiers difficult, leading to inaccurate classification. Therefore, an object-based classification is a potential solution for the classification of land cover in Mediterranean regions. The specific benefits are an increase in accuracy, a decrease in classification time and that it helps to eliminate within-field spectral mixing (Berberoglu et al., 2000). The object-based classification approach involved the integration of vector data and raster images within a geographical information system (GIS) and enabled the knowledge free extraction of image object primitives at different spatial resolutions, the so-called multiresolution segmentation. The segmentation operated as a heuristic optimization procedure which minimized the average heterogeneity of image objects at a given spatial resolution for the whole scene (Bian et al. 1992). The objective was to construct a hierarchical net of image objects, in which fine objects were sub-objects of coarser structures. Due to the hierarchical structure, the image data were simultaneously represented at different spatial resolutions. The defined local object-oriented context information was then used together with other (spectral, form, texture) features of the image objects for classification. At the next stage, supervised per-field classification was performed using the nearest neighbour algorithm utilising field boundary data generated as a result of the segmentation procedure. Objects are segmented in the image and all objects are created object layer. Two or more object layer is called object hierarchy (Figure 30).

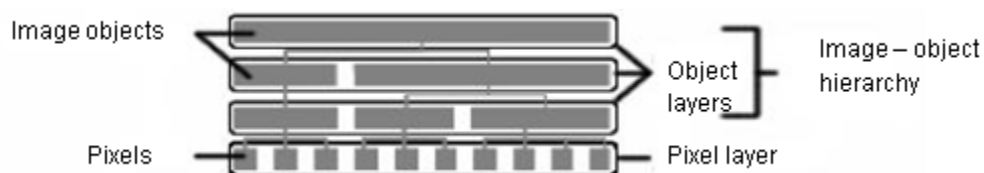


Figure 30. Image object hierarchy

Object based classification and expert knowledge classification techniques were used for mapping the agricultural crop pattern in winter and summer periods. The largely used pixel based techniques were tested to find the most accurate classifier and accuracy was derived using error matrix. Rule based classification was applied to reduce the misclassification, using ancillary data such as Normalized Difference Vegetation Index (NDVI), distance from sea, distance from lagoon, distance from river, distance from settlements and roads, agricultural area map and mask of citrus plantations. As a result, crop pattern maps were produced accurately (figure 31).

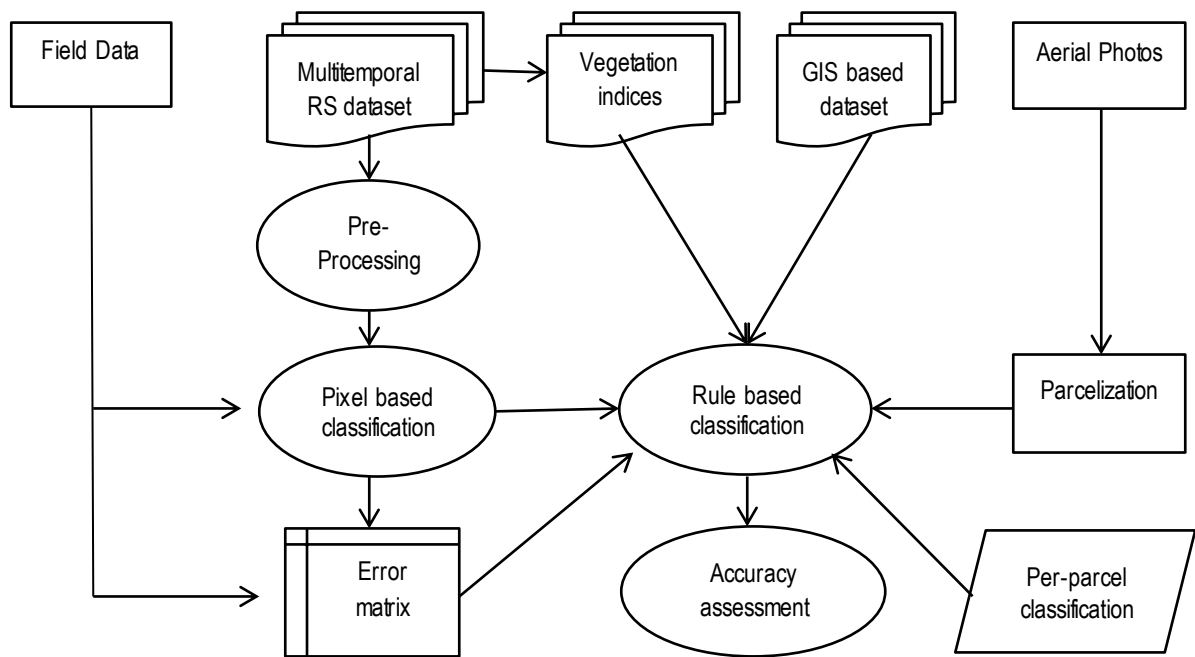


Figure 31. Flow-diagram of the classification scheme

Statistical wheat yield analyses

Stepwise linear regression technique was applied for the yield estimation. Linear regression refers to relating a response variable Y to a set of predictors xi in the form (Chatterjee and Price, 1991):

$$Y = b_0 + b_1.x_1 + b_2.x_2 + \dots + b_p.x_p \quad (1)$$

Where the b_0 is the constant value and b_1 refers to coefficient of the first variable x_1 (waveband). An advantage of linear regression is that it is easy to implement. Multi linear regression models are computationally efficient and can also predict confidence intervals for the obtained coefficients and the predicted data. Some of variable was eliminated using stepwise, backward, forward regression models. The most accurate model was applied according to significance and R^2 values of the equations.

Real yield data and seven vegetation indices were used as target and predictor variables respectively. Normalized difference vegetation index (NDVI), normalized difference water index (NDWI), soil adjusted vegetation index (SAVI), perpendicular vegetation index (PVI), weighted difference vegetation index (WDVI), green vegetation index (GVI) and landsat tasseled cap moisture index (MOIST) were derived from Landsat ETM data (Table 5).

Table 5. Vegetation indices and specifications

Index	Equation	Specification	Reference
NDVI	$b_4 - b_3 / b_4 + b_3$	Chlorophyll content	<i>Rouse ve ark. (1973)</i>
NDWI	$b_4 - b_5 / b_4 + b_5$	Plant water	<i>Gao (1996)</i>

SAVI	$(b4 - b3 / b4 + b3 + L) * (1 - L)$	stress Chrolophyl content	<i>Huete (1988)</i>
PVI	Pythagorean Relation	Chrolophyl content	<i>Thiam (1999)</i>
WDVI	$b4 - S_L * b3$	Chrolophyl content	<i>Richardson ve Wiegand (1977)</i>
GVI	$(b1 * -0.2848) + (b2 * -0.2435) + (b3 * 0.5436) + (b4 * 0.7243) + (b5 * 0.0840) + (b7 * -0.1800)$	Plant green structure	<i>Mather (1999)</i>
MOIST	$(b1 * 0.2626) + (b2 * 0.2141) + (b3 * 0.0926) + (b4 * 0.656) - (b5 * 0.7629) - (b7 * 0.5388)$	Soil water stress	<i>Huang ve ark. (2002)</i>

RESULTS

Rule based per-parcel classification approach was applied to map crop pattern and land cover in LSP. The largest classification accuracy was resulted from this technique for 2011 and 2012 with kappa statistics of 90% and 91% respectively.

Vegetation indices were derived for wheat yield analyses. A reliable and useful model developed using Landsat TM/ETM dataset to detect wheat yield.

Agricultural Crop Pattern Mapping

Agricultural crop pattern was mapped for 2011 and 2012 in winter and summer period. GIS based ancillary data integrated to the classifications in a rule based interface to improve the accuracy. Parcel map of the LSP was used in per-parcel classification stage applying zonal analyses based on majority filter.

Multi-temporal remotely sensed dataset was used for mapping the agricultural patterns in non-stable area like LSP. The main remote sensing database was Landsat. However, Landsat mission has been stopped until coming Landsat 8 in 2013. Therefore, ASTER and SPOT data were used to cover the 2012 summer period. The last Landsat data acquired for June 2012 and SPOT data was used for July, however second crops are detected in August. ASTER image recorded in August was used to map the second crop corn, cotton, soyabean and ground nut (Figure 32). Winter 2012 crop pattern was classified using March and May Landsat ETM data (Figure 33).

Additionally, summer and winter 2011 crop patterns were classified using only multitemporal Landsat TM/ETM dataset with the same techniques to compare yearly changes in LSP for winter and summer period (Figures 34 and 35).

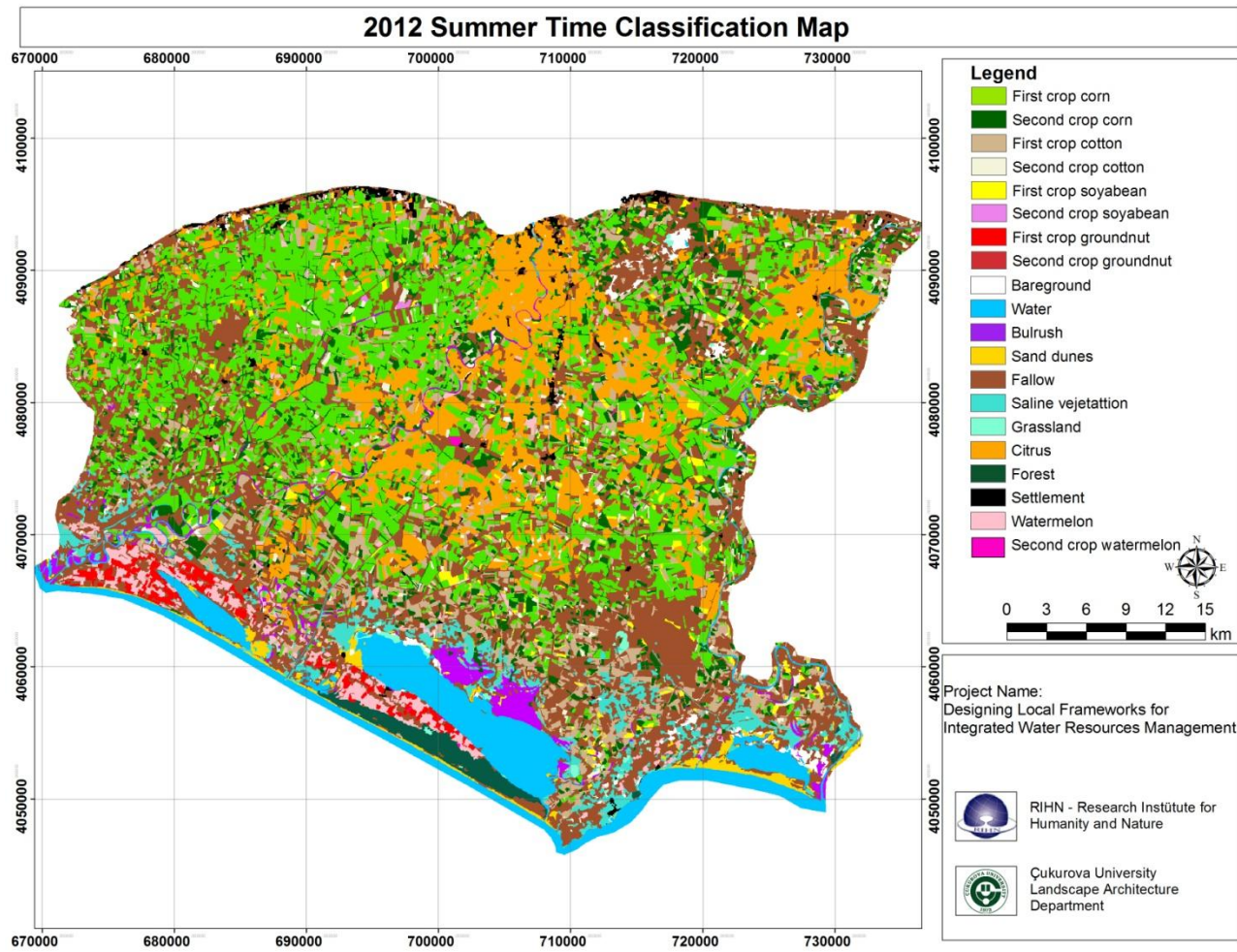


Figure 32. Summer 2012 crop pattern of LSP

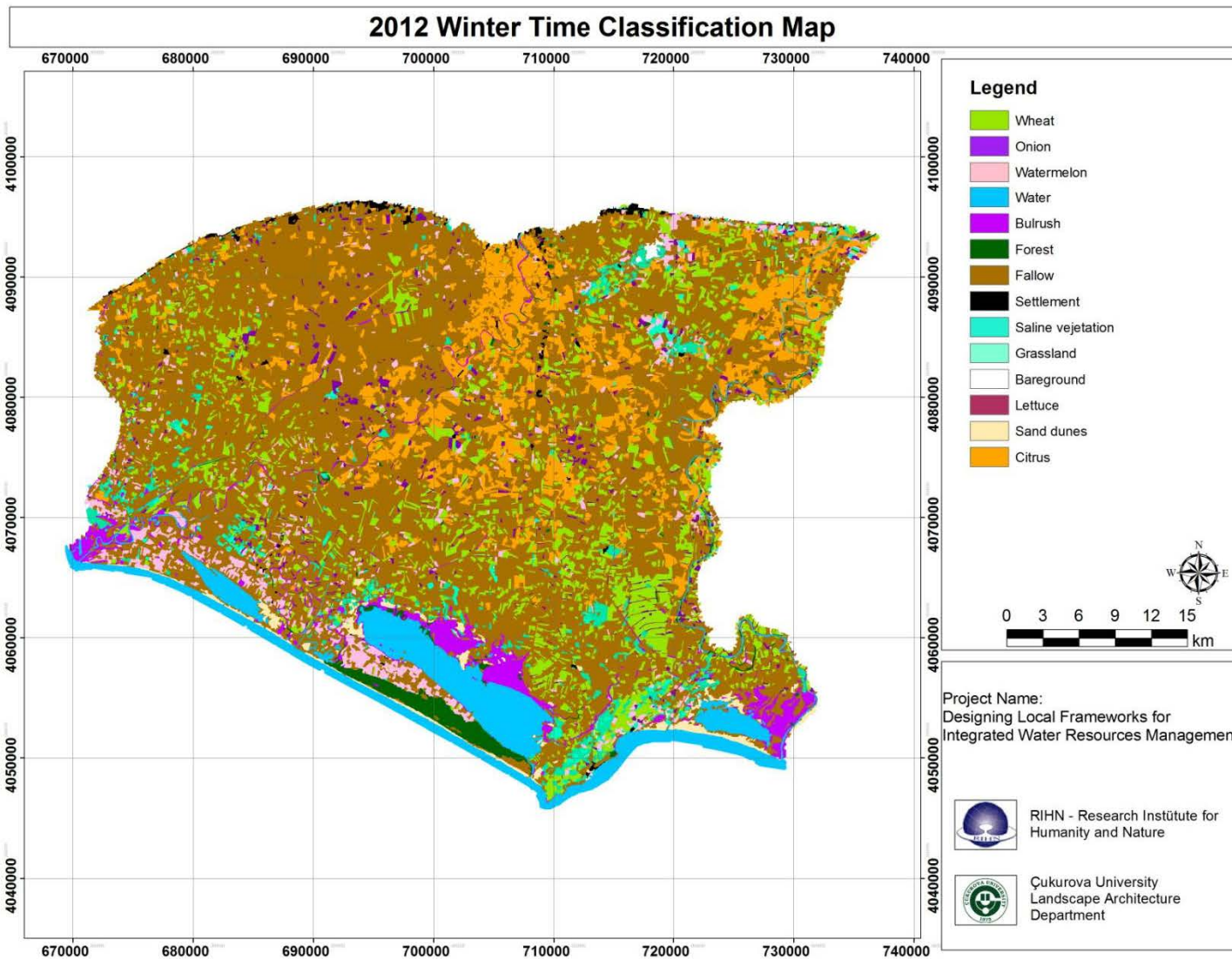


Figure 33. Winter 2012 crop pattern of LSP.

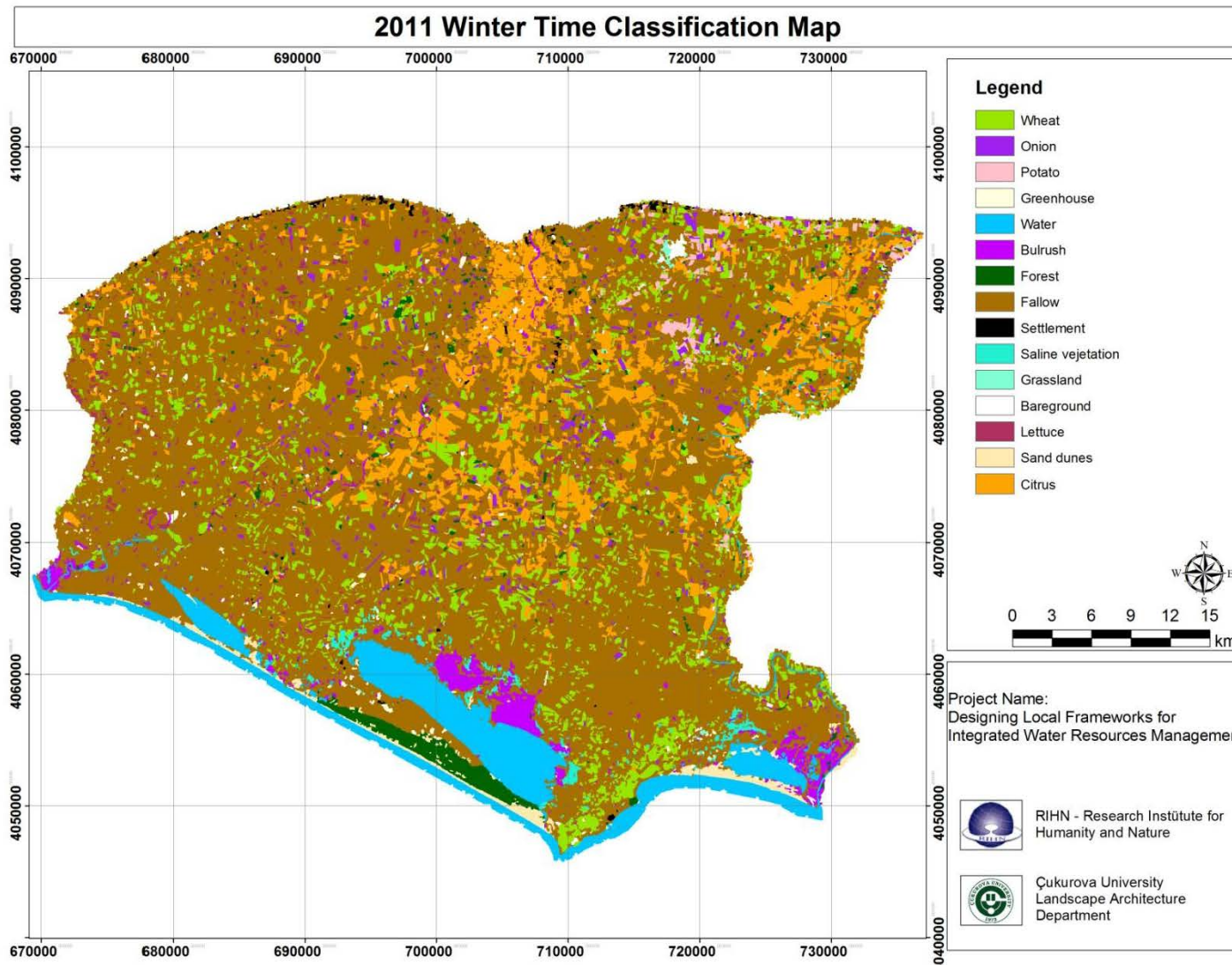


Figure 34. Winter 2011 crop pattern of LSP.

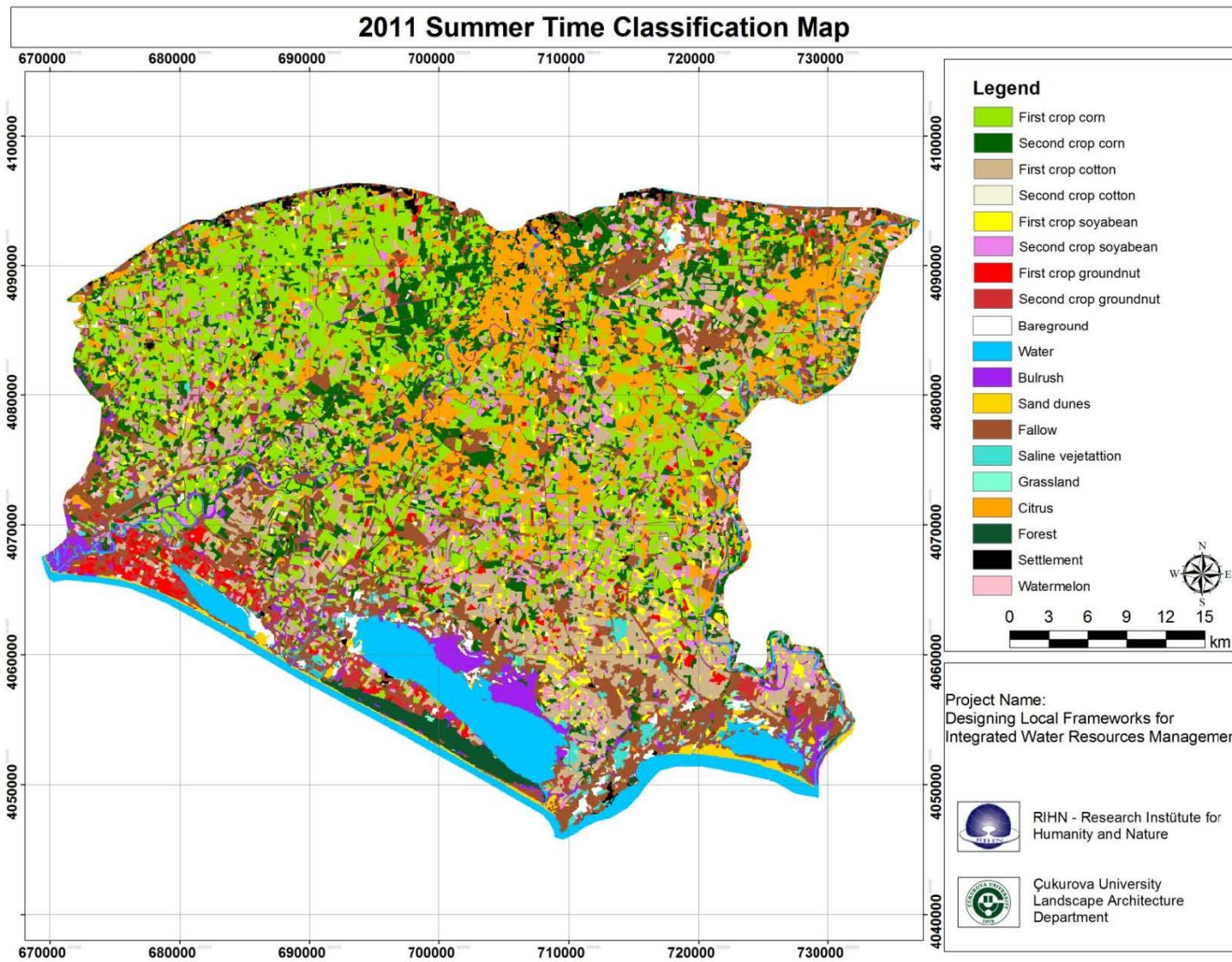


Figure 35. Summer 2011 crop pattern of LSP.

Agricultural crop pattern of 2011 and 2012 was analyzed (Table 6). Results showed that wheat areas were increased by 5450 ha. Farmers preferred corn as first crop because of government subsidy. However, citrus, second crop cotton and watermelon cultivation were increased between 2011 and 2012. While, soyabean and groundnut production were decreased in general (Figure 36). However, second crop groundnut and lettuce areas cannot be detect clearly because of cloud free remotely sensed data availability.

Table 6. 2011 and 2012 winter and summer LUC (Land Use/Cover) difference

LUC	Winter (ha)			Summer (ha)		
	2011	2012	Difference	2011	2012	Difference
Bareground	268	195	-73	1481	1717	236
Fallow	137849	129348	-8501	34689	59965	25276
Wheat	18222	23674	5452	-	-	-
Grassland	2440	1819	-621	2865	648	-2217
Sand dunes	2188	2335	147	1723	1989	266
Citrus	25600	26400	800	25649	30028	4379
Forest	3628	3628	0	3628	3628	0
Potato	1231	845	-386	-	-	-
Bulrush	3790	3900	110	5635	3305	-2330
Onion	3395	4200	805	-	-	-
Lettuce	3726	*	-	-	-	-
Water	14311	14676	365	14563	14231	-332
Saline vegetation	7050	5430	-1620	8329	6211	-2118
Settlement	1850	1850	0	1851	1851	0
First crop corn	-	-	-	45827	51582	5755
Second crop corn	-	-	-	28912	16888	-12024
First crop cotton	-	-	-	24022	20297	-3725
Second crop cotton	-	-	-	815	3413	2598
First crop groundnut	-	-	-	3478	1985	-1493
Second crop groundnut	-	-	-	2854	*	-2854
Watermelon	-	7130	7130	3068	4900	1832
First crop soya bean	-	-	-	6131	2345	-3786
Second crop soya bean	-	-	-	9155	198	-8957

* No-data because of satellite imaging period.

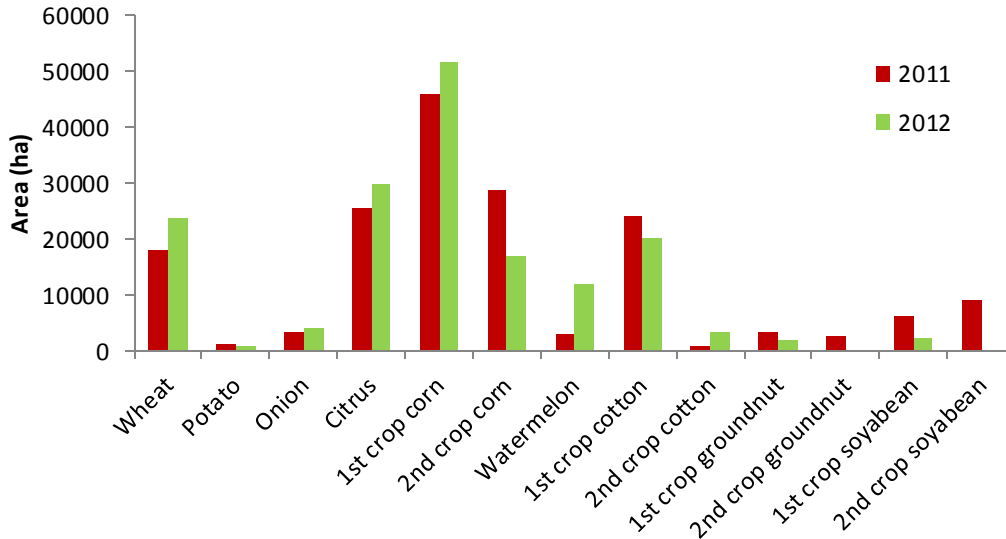


Figure 36. Agricultural crop pattern between 2011 and 2012 in LSP

Classification Accuracy Assessments

The error matrix is one the widely used accuracy assessment technique (Foody 2002). In order to properly generate an error matrix, one must consider the following factors: (1) reference data collection, (2) classification scheme, (3) sampling scheme, (4) spatial autocorrelation, and (5) sample size and sample unit (Congalton and Plourde 2002). Generation of an error matrix enables to derive other important accuracy assessment elements, such as overall accuracy, user accuracy, producer accuracy, and kappa coefficient. Kappa is the difference between the observed accuracy and the chance agreement divided by one minus that chance agreement (Lillesand and Kiefer 1994).

Kappa co-efficiencies of 2012 crop pattern classifications were derived using ground truth dataset where is collected during the field works in each crop rotation period (Figure 37).

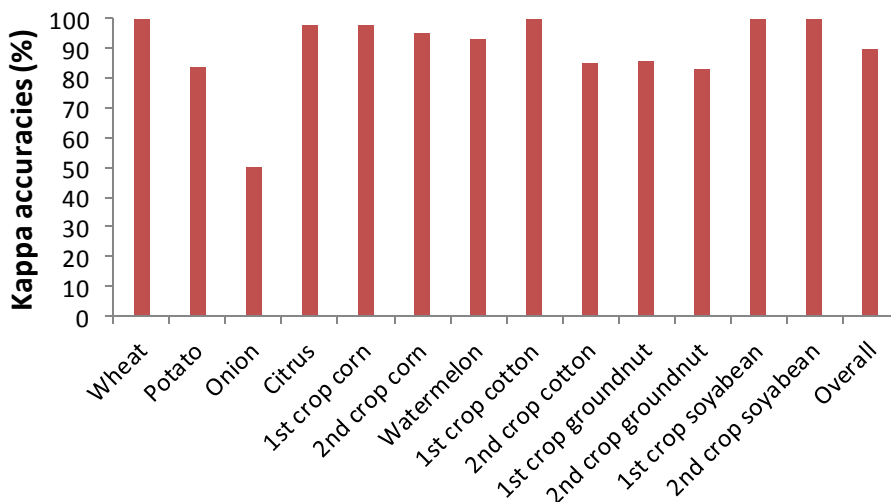


Figure 37. Classification Accuracy of the agricultural crops

Wheat Yield Estimation

Wheat productivity of LSP in 2010, 2011 and 2012 were estimated using remote sensing techniques. In this research, vegetation indices of Landsat TM/ETM data were correlated with real time wheat yield data using several regression statistics as SLR (stepwise linear regression), PLSR (partial least square regression) and POWER regression. These three techniques were compared and the best one was applied to estimate wheat yield in the LSP.

Seven Landsat vegetation indices were derived as NDVI, NDWI, PVI, GVI, WDV, SAVI and MOIST. Yield data was collected from almost 25 fields speaking with the farmers. Firstly, SLR technique was applied. This technique has an advantage that eliminates unnecessary inputs. Following equation was resulted from SLR statistics:

$$\text{Yield} = 166.277 + 30.128 * \text{NDWI} + 631.257 * \text{NDVI} + 903.214 * \text{MOIST} \quad (2)$$

Plant water content (NDWI), plant chlorophyll content (NDVI) and soil moisture content (MOIST) within the regression equation were detected as the most descriptive predictors for wheat yield estimation. Other vegetation indices were unnecessary for predicting the yield. Accurate models including less input are the most applicable. Therefore, SLR eliminates uncorrelated inputs and increases accuracy (Berberoglu et al, 2009).

Secondly, only one vegetation index was used to estimate the wheat yield. The largest relationship was derived from NDVI and a power regression was applied using only one index.

$$\text{Yield} = 731.59 * \text{NDVI}^{0.8782} \quad (3)$$

Model validation was tested in alpha 0.05 and it was detected as a reliable and applicable model (Table 7).

The last regression model was partial least square regression (PLSR). This method is very effective when the input data larger than target variables. This situation is not applicable for this study, however this model was used to assess the performance in wheat yield estimation.

$$\text{Yield} = 300.389 * 101.197 * \text{WDVI} + 124.108 * \text{SAVI} - 135.467 * \text{PVI} + 54.139 * \text{NDWI} + 123.285 * \text{NDVI} + 395.968 * \text{MOIST} + 145.638 * \text{GVI} \quad (4)$$

Table 7. Model validation results.

Method	R	R ²	RMSE	F	P
SLR	0.815	0.665	54.84	7.941	0.003
POWER	0.862	0.742	62	40.352	0.00001
PLSR	0.70	0.48	46.87	21.54	0.00001

Data from 17 fields were used to create the model and 8 of them were separated for testing the results. Resulted determination coefficients of 0.82, 0.70 and 0.64 were derived using SLR, POWER, PLSR respectively (Figure 38).

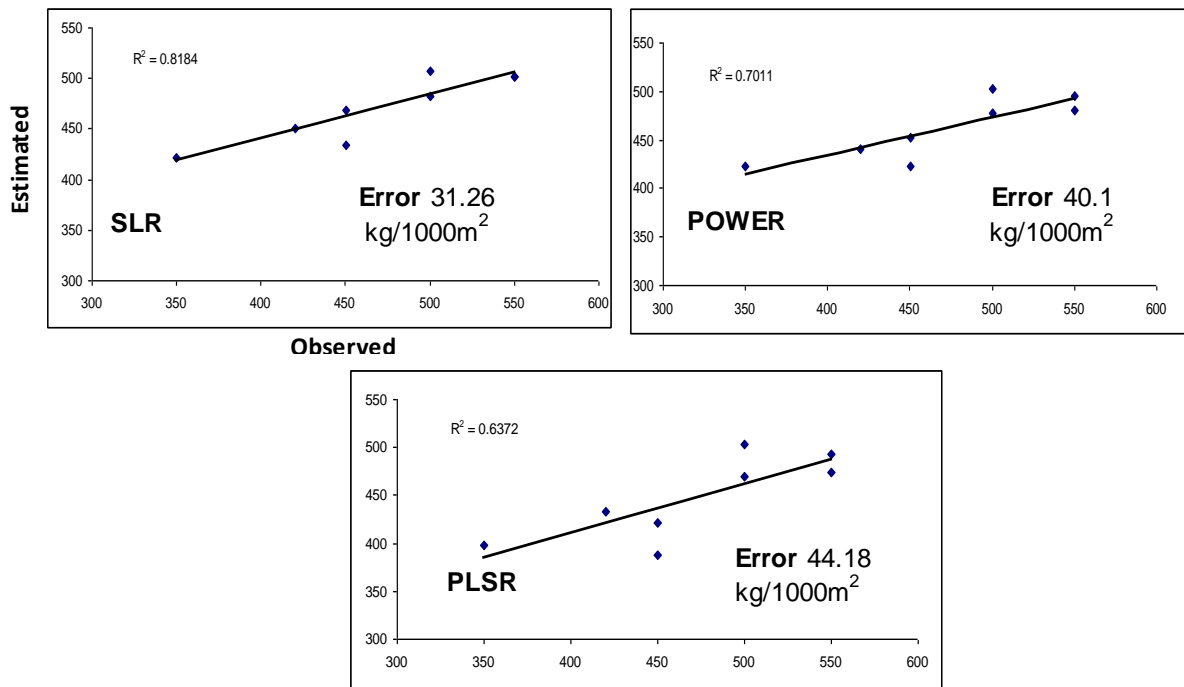


Figure 38. Accuracy results of the SLR, POWER and PLSR techniques

The lowest error was derived using SLR technique. 2010, 2011 and 2012 wheat yields were estimated using SLR (Figures 39, 40, 41) and agricultural efficiencies were calculated using total wheat area and total yield ratio (Table8).

Table 8. Comparison of agricultural efficiency, wheat yield and total wheat area

Wheat yield	Total area (ha)			Total yield (ton)			Agricultural efficiency*		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
	27729	18222	23674	116632	94058	94536	4.2	5.16	3.99

* Agricultural efficiency = Total yield / Total area

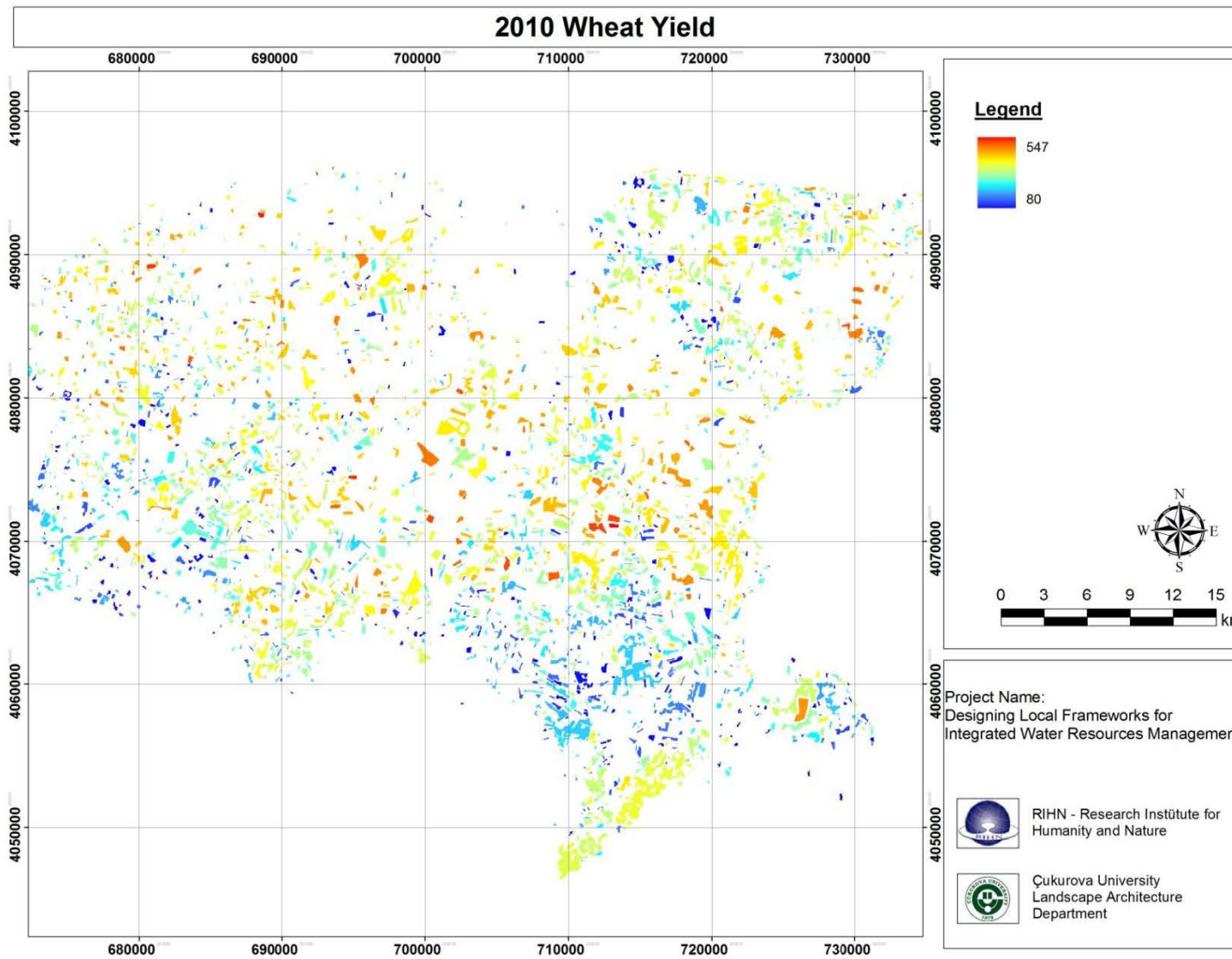


Figure 39. Wheat yield map of 2010.

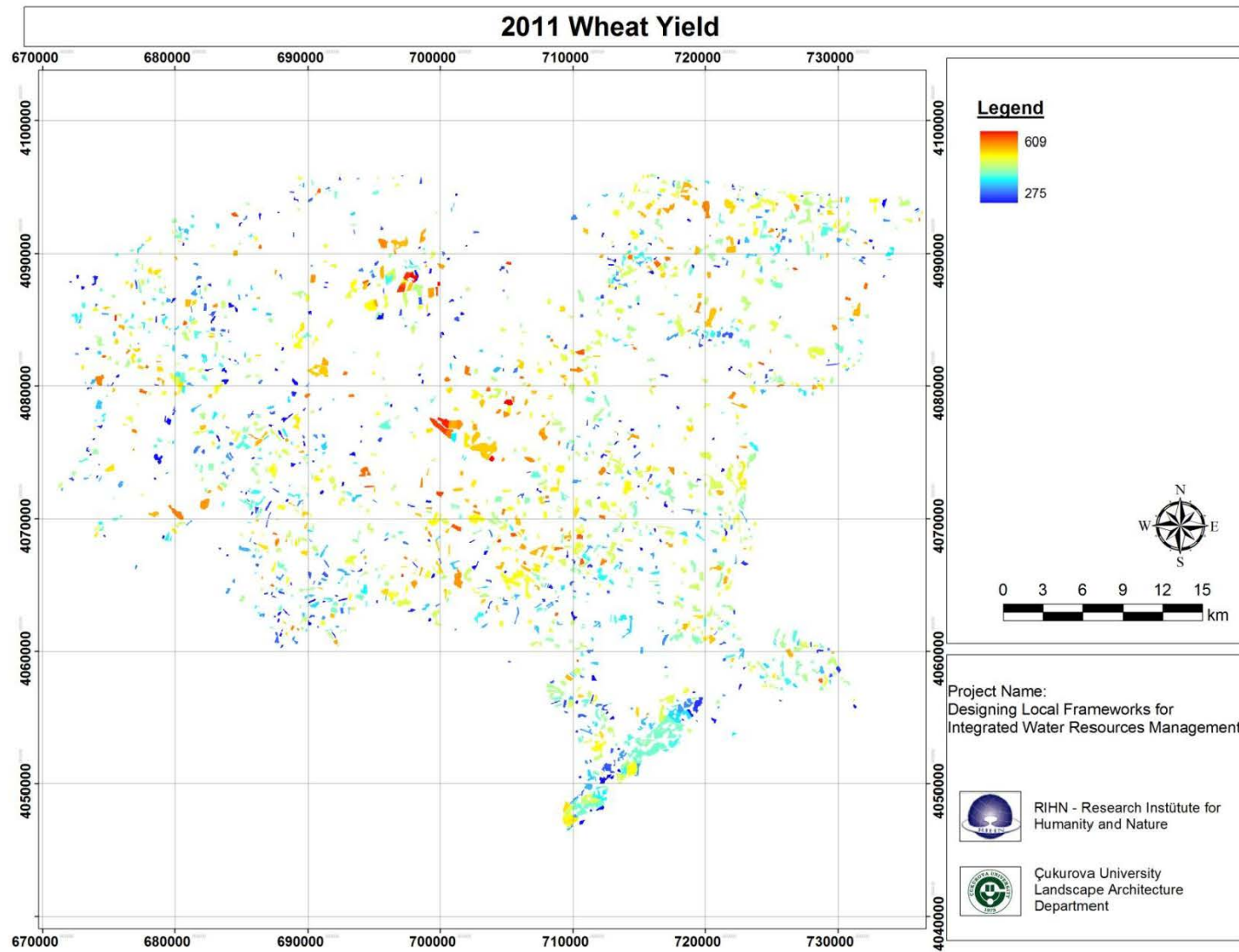


Figure 40. Wheat yield map of 2011.

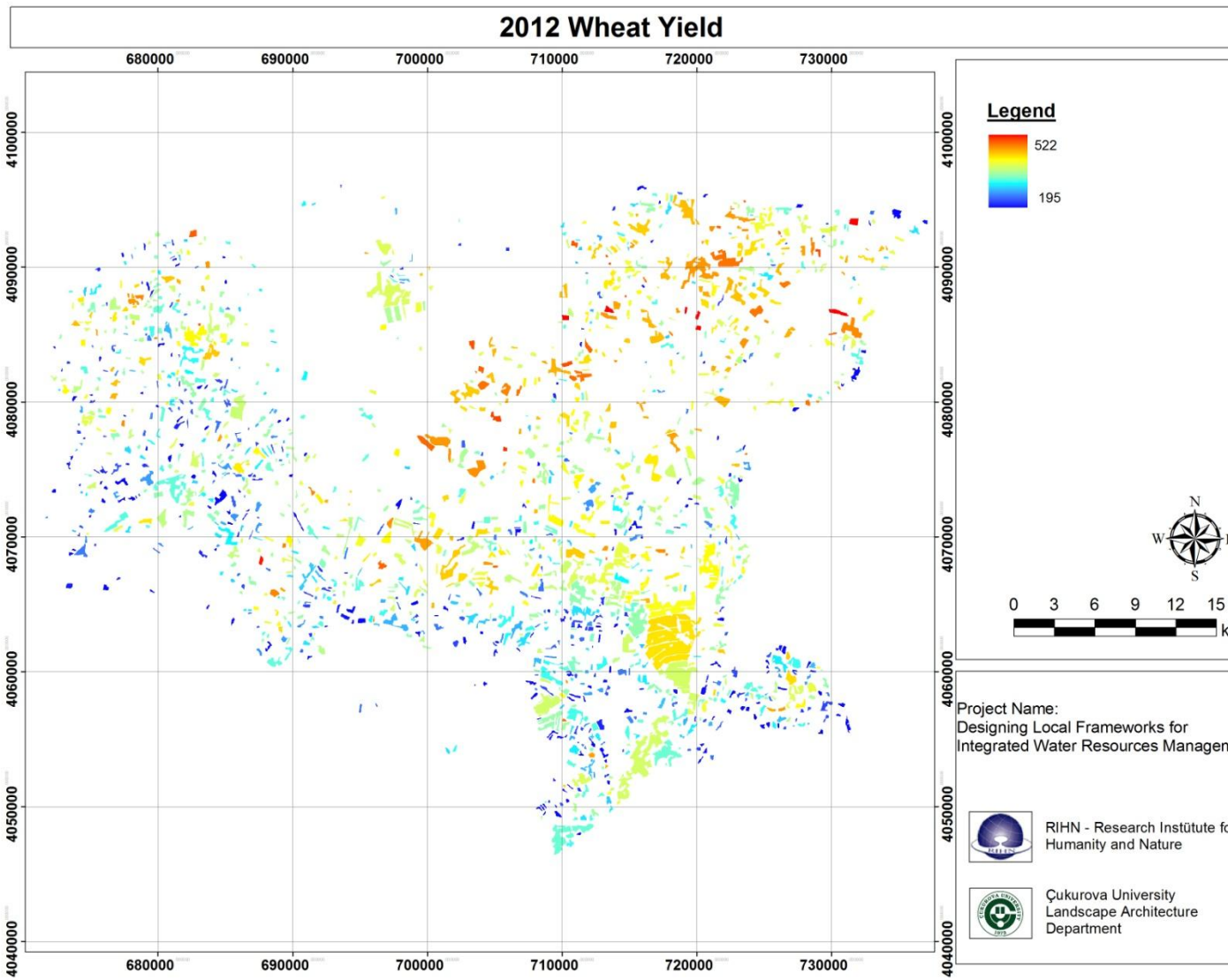


Figure 41. Wheat yield map of 201

Ongoing and Future Activities in Socio-Economic Group

- Draft questionnaire is under preparation and will be discussed with Dr. Hamasaki. The first draft is enclosed to this report (Annex 1).
- The questionnaire will be pre-tested in the Lower Seyhan Basin before its application to selected farmers. Additionally, secondary data such as previous studies already carried out on the similar topic and the output statistics will be used to facilitate and support the research.
- Selection of the farmers by using suitable sampling methods. In this case, the “judgement sampling” method will be used in selecting the villages. Soil classes, cropping pattern, agricultural production techniques, economic structure and distribution of farms will be taken into consideration as criteria in selecting the farms.
- The farms in the villages will be stratified according to farm size groups. From each group a representative number of farmers will be interviewed. The farmers will be selected randomly and those who are willingly and voluntarily cooperate with the researches.
- Conduct our farm household survey in Lower Seyhan Basin, in order to identify the current situation of the farm economy, planting strategies, rotation principles and farmers’ perception.

ANNEX 1.

DRAFT QUESTIONNAIRE

We need to work on it, improvement is needed..

Name of Village _____

Date of Interview _____

Name of District _____

Household Id.Number _____

Name of City _____

Name of Head of Household _____

Name of Enumerator _____

Name of Respondent _____

M/No.	Relation to the HH. head	Sex	Age	Present marital status	Education		Main occupation
					Highest school she/he enrolled	Complete or Incomplete	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Total area cultivated in 2010 -2011 (da) (including Ownership-hired-collective):

Total area cultivated in 2011-2012 (da) (including Ownership-hired-collective):

LAND TENURE AND FARM MANAGEMENT

If your family possesses a farm land, or manages a farm, please tell me the detail of the possessing situation and the cropping history of the latest year.

S/No.	Size (da)	Ownership	Utilization	Irrigation	Land rent (TL/da)	Crop1 (note 1)					Crop2				
						Crop	Production amount (kg)	Sales amount (kg)	Home consumption (kg)	Market price (TL/kg)	Crop	Production amount (kg)	Sales amount (kg)	Home consumption (kg)	Market price (TL/kg)
1															
2															
3															
4															
5															
6															
7															

EQUIPMENT

Name of equipment	Item	ownership	How old
Tractor			
Plow			
Sowing machine			
Kültivator			
Disc harrow			
Harrow			
Holder			
Combined harvester			
Hoeing machine			
Fertiliser machine			
Springler			

Bovine animal	sheep and goats

LABOUR FORCE

	Household agricultural activities (days)	On farm hired labour (days)	Off farm hired labour (days)	Trading activities (days)	Non workers
N°of family member					

HOUSEHOLD ECONOMY

- OFF FARM INCOME

On farm hired labour wage	
Off farm hired labour wage	

- FAMILY LIVING EXPENDITURES

Food	
Clothes	
Rent	
School	
....	

- SAVING CAPACITIES

--	--

- REINVESTMENT

Technologies	
Inputs	
Machineries	
Education	
.....	

NAME OF CROP AND PARCEL SIZE:

SOIL PREPARATION-MAINTENANCE

Tasks	Date of tasks	Lobar force requirement			Machine usage		
		Labor (hour/da)	Family or outside	Fee (TL/hour)	Equipment used	Duration of work (hour/da)	Fee at the application period (TL/hour -TL/da)

NAME OF CROP AND PARCEL SIZE:

FERTILISING

Type of fertilyser used in detail	Date	Timing (Before sowing, with sowing, before irrigation, etc.)	Application prosedure	Amount applied (Kg/da)	Unit price (TL/kg)	Lobar force requirement			Machine usage		
						Labor (hour/da)	Family or outside	Fee (TL/hour)	Type	Time duration (hour/da)	Fee at the used date (TL/hour-TL/da)

Did you have soil analysis done before fertilisation ? Yes No

If yes, When?

If not, How do you decide about the amount of **fertilizer**?

Do you use manure or green fertilizer?

How many days after or before you fertilize you crop?????
 Percentage of fertilizer by drip irrigation

NAME OF CROP AND PARCEL SIZE:

PESTICIDES APPLIED

Commercial name	Date of application	How many times applied	What for? Target Pest/disease	Level of infestation Severe (S), Moderate (Mo), Mild (Mi), Do not know (DN)	Amount used (kg-gr/da)	Unit price (TL/kg)	Lobar force requirement			Machine usage		
							Labor (hour/da)	Family or outside	Labor (hour/da)	Equipment used	Work duration (hour/da)	Fee at the used date (TL/hour-TL/da)

--	--	--	--	--	--	--	--	--	--	--	--	--

Do you get expertise before applying it? Yes No

If so, How much did you pay?

If not, how do you decide to use a pesticide? Effective/ Cheap/ Fast action/ others

And how did you decide over the amount?

The applied amount compared with the prescribed or recommended? less than same more than

Weed control by herbicide others (hoeing etc.)

NAME OF CROP AND PARCEL SIZE:

IRRIGATION

Irrigation applications (Constructing borders, furrows, first irrigation, second irrigation etc.) ???	Date and timing	Type of Irrigation	Irrigated area	Machinery usage			Labor force requirement		
				Equipment used	Duration of work (hour/da)	Renting price at application date (TL/hour - TL/da)	Labor force (hour/da)	Family-Outside	Price/fee (TL/hour)

Water price per decare (TL):

Water availability? More than needed/Sufficient /Scarce

Water source?

	Type of irrigation			
	Surface irrigation	sprinkler irrigation	Drip irrigation	Other
How many siphons / pipes do you use for the irrigation ?				
What is the length of pipes ?				
What is the size of siphons / pipes ?				
Do you use all the siphons / pipes for the irrigation ?				

What is the length of one furrow in your land? Do you irrigate all the furrows at once?				
What is the duration that one siphons / pipes is open ?				
What is the total duration of irrigation?				
How do you decide to terminate irrigation?				
How do you decide to start irrigation?				
If you pay any fee per hour for the irrigation, what do you do? Do you change your irrigation system?				
Are you using any methods to conserve water condition of managed land? If no, what can be done?				
Do you irrigate your land in the day time or in the night? Which one do you prefer? Why?				
What is the cost of irrigation system?				

NAME OF CROP AND PARCEL SIZE:

HARVESTING AND MARKETING

Procedure and tasks	Date of procedure	Labor force usage			Equipment usage			Material usage		
		Labor force (hour/da)	Family-outside	Price (TL/hour)	Equipment used	Duration of work (hour/da)	Rent at the application period (TL/hour -TL/da)	Type	Amount (kg veya adet)	Unit price (TL/kg)

PRODUCTS AND YIELD

Main and byproduct	Yield (kg/da)	Total production (ton)	Sale price (TL/kg)	Who bought it?	Place of marketing	Form of sale	Days elapsed to sell the product after harvesting

DESTINATION OF PRODUCTION

	Kg
Own consumption	
Seeds	
Selling	
Raising livestock	
Storing	

Have you already paid withholding tax? If yes, how much?

If the yield is low or high compared to the yields of last years, the possible reasons might be:

process of commercializing ?

Are you trying to find new markets for your crops?

Dou you know anything about organic farming? Do you want to deal with this subject?

Expences

Total farm cost (TL)

Crop

Seed Cost	Fertilizer Cost	Pesticide Cost	Labor Cost	Water Cost	Others

Others

Oil	Fuel	Repaire of Deadstocks	Transportation Cost

Loan Condition

Are you a member of Agricultural Credit Cooperation (TKK)? Yes/No

If No, why don't you become a member of TKK?

Had you borrowed money from any credit institutions(ACC and etc...) in last ten years? Yes / No

Are you active member of any kind of farmers' cooperative?

Loan History

	Year	Source 1					Source 2					Source 3				
		Source (Code 1)	Purpose (Code 2)	Amount (TL)*	Period (Years)	Interest/ Year	Source (Code 1)	Purpose (Code 2)	Amount (TL)*	Period (Years)	Interest/ Year	Source (Code 1)	Purpose (Code 2)	Amount (TL)*	Period (Years)	Interest/ Year
1																
2																
3																

Code 1: Relatives(1), Friends(2), Cooperatives(3), Money lender(4), NGO(5), Commercial Bank(6), Government Bank(7), Trader(8), Sublease what Relatives and Friends Borrowed from ACC(9) , Others(10)

Code 2: Agricultural Production(1), Consumption(2)

*When the farmer bought fertilizer and pesticide on credit (a loan) from TKK, please write down kind and amount(kg).

How did you use these loans? (The newest one only, Please answer by Percentage)

	Agricultural Production			Consumption				Other
	Farm Inputs (seed, Fertilizer, Pesticide)	Other Inputs (Irrigation, labor, etc)	Farm Equipments	Usual consumption (Food, Clothes, etc)	Health/ Education	Construction	Social (Wedding, Funeral, etc)	
Source 1								
Source 2								
Source 3								

When farmers do not count with any credit... Which are the reasons?

- Lack of information about sources of credit?
- Lack of information about requirements/procedures to get a credit?
- Unfeasibility to fulfill requirements

Adoption of soil/water/environment/conservation technologies:

Are you using any methods to conserve soil/water/environment condition of managed land? Yes / No Why?

Name, starting year, purpose and detail of the methods

Name of the method	Starting year	Purpose of using it	Detail of the method
Tillage conservation			
Application of manure			