DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

SPATIAL-TEMPORAL AGRICULTURAL INFORMATION SYSTEM TO OPTIMIZE PESTICIDE USAGE BY CREATING A BUFFER-ZONE

by
Peter AYEBARE

August, 2015
İZMİR

SPATIAL-TEMPORAL AGRICULTURAL INFORMATION SYSTEM TO OPTIMIZE PESTICIDE USAGE BY CREATING A BUFFER-ZONE

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled "**SPATIAL-TEMPORAL AGRICULTURAL INFORMATION SYSTEM TO OPTIMIZE PESTICIDE USAGE BY CREATING A BUFFER-ZONE**" completed by **PETER AYEBARE** under supervision of **ASST. PROF. DR. CANAN EREN ATAY**, and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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I thank God for all the providences during my stay in Turkey.

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ABSTRACT

The estimation of agriculture yields is a challenging and suitable task for every farmer. In the world economy, agriculture sector plays a big role. In most countries worldwide, their populations most likely above seventy percent practice and depend on agriculture produces for feed their lives and earning incomes. Today, farmers do not only produce yields but also generate huge amounts of agricultural data. This data can be collected, stored and analyzed for useful information. In an attempt to increase agriculture produce, farmers tend to apply excessive pesticides. This has led to spray drift problem whenever liquid sprays are applied and hence causing harm to adjacent crops and other non-target areas. A lot of research has been carried done to mitigate the problem of pesticide spray drift by erosion. However, research has been carried out on pesticide drift by agents such as wind, boom height, driving speed but not to the extreme. Therefore, our research focuses on creating a buffer zone as measure to counter rampant spray drift during pesticide application. In this research, a GIS model was used to capture spray area (farm) points. The spray drift distance that was obtained using the mentioned agents above, was appended to these geographic points of the farm to create a buffer zone area. This thus can be essential for optimizing pesticide usage and better management.

Keywords: Precision agriculture, GIS, spatiotemporal, spray drift, buffer zone.

KORUMA ALANI OLUŞTURARAK İLAÇ KULLANIMI EN İYİLEYEME KONUMSAL-ZAMANSAL TARIMSAL BİLGİ SİSTEMİ

ÖZ

Tarımsal ürünlerin verimlerinin tahmini her çiftçi için zor ve olması gereken bir görevdir. Ekonomi dünyasında tarım sektörünün rolü büyüktür. Dünyadaki pek çok ülkenin nüfuslarının büyük olasılıkla yüzde yetmişinden fazlası geçinmek ve gelir kazanmak için tarımla ve tarımsal ürünlerle uğraşır. Günümüzde çiftçiler sadece tarımsal ürün değil, aynı zamanda büyük miktarlarda veri üretmektedir. Bu veriler toplanabilir, saklanabilir ve faydalı bilgilere ulaşmak için analiz edilebilir. Çiftçiler tarımsal ürünlerdeki verimliliği arttırmak için gereğinden fazla ilaçlama yapma eğilimindedirler. Sıvı ilaçlama uygulandığı zaman bu püskürtme sapma sorununa yol açmaktadır ve dolayısıylakomşu ürünlere ve hedef dışındaki alanlarda zarara neden olmaktadır. İlaç püskürtme sapma problemindeki toprak aşınmasını azaltmak için pek çok araştırma yapılmıştır. Püskürtme sapma ile ilgili araştırmalar rüzgar, ürün yüksekliği, sürüş hızı gibi etmenler için yapılmıştır fakat yeterli değildir. Bundan dolayı bizim çalışmamız ilaçlama uygulama esnasında her tarafa yayılan püskürtme sapma ölçümüne karşı koruma alanı oluşturmaya odaklanır. Bu araştırmada tarımsal püskürtme alanını belirlemek için Coğrafi Bilişim Sistemleri modeli kullanılmıştır. Daha önce belirtilen etmenler kullanılarak bulunan püskürtme sapma mesafesi koruma alanı oluşturulması için tarımsal bölgenin coğrafi noktalarına eklenmiştir. Sonuç olarak bu ilaç kullanımı ve daha iyi yönetimin en iyilenmesi için önemlidir.

Anahtar Kelimeler: Hassas uygulamalı tarım, CBS, konumsal-zamansal, püskürtme sapması, koruma alanı.

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CHAPTER ONE
INTRODUCTION

1.1 Background

As population increases rapidly worldwide, the necessity of having enough food to feed everyone increases as well. Most countries in the developing world are predominantly agriculture based with approximately two third of their populations practicing agriculture. With inefficient farming practices agricultural sector continues to face a pack of challenges in order to maximize efficiency in crop production. While, this is one of the most crucial troubles that have been interfaced with ever, farmers haven't received enough support for raising harvests of greater quality and quantity.

One of the major reverse in agriculture sector is the excessive pesticide usage in association with guidance and timely information. Exuberant use of pesticide is abusive and harmful in multiple ways. On one hand, farmers have always had to pay highly for pesticides; while on the other hand, an increase in pesticide usage develops immunity in pests hence making them more harmful to crops (Abdullah et al., 2004). Thus, farmers are following unscientific cultivation practices mostly provided by local pesticide marketers. As a result, the farmers are employing wrong, untimely and excessive pesticides. This can result in devastating environment and public health. In addition, indiscriminate usage of pesticides is also harming nature and other non-target organisms. The use of these pesticides in the farmlands affects human health, even causing fatal diseases to the consumers when they get these active substances into their bodies.

When pesticides are applied, a key issue is the risk of 'spray drift' beyond the field boundary. This usually occurs when the wind velocity is strong enough to break up and carry away the spray droplets. Small droplets drift further than large droplets. Granular and powder formulations will also drift. This is an important and costly problem facing commercial and private applicators. Drift causes damage to susceptible off-target sites, a lower rate than intended on target, which can reduce the effectiveness of the pesticide. In addition to these, it results into environmental contamination, such as water pollution and illegal pesticide residues.

Farmers who don't practice farming consciously may use a great batch of pesticides, which contain carcinogenic substances. Of the use of such substances in the farmlands are of great concern to the consumers and dealers. Agriculture engineers are supposed to consult farmers about when and how to cultivate, fertilize, and harvest their crops, but not every farmer receives such professional help, because of the physical distances between them. Consequently, they make decisions based upon their instincts, and thus they end up losing time and money. Consumers not only must pay the high prices, but also they generally don't know what kinds of pesticides are contained in the food they purchase. It would be of great value to have a web-based information system that farmers, dealers, agriculture engineers, and consumers could utilize to share information for better, cheaper, and healthier products as well as recommendation pesticide usage on crops.

Another problem that farmers face is selling their harvest at an appropriate price and time, before the harvest rots, awaiting shipment to the final food processors. Dealers control prices locally by offering farmers to buy their harvests and then sell them to markets further down the chain. Farmers have to accept dealers' bids, even if it is lower than the real value. Dealers sometimes are not able to find suitable products/harvests in their area to buy from farmers and sell to markets, either locally or in other countries. Even if they find such foodstuffs, the products may not be in the condition they desire. Dealers are dependent upon the farmers in their respective territories. When they try to find an agricultural product to buy, they typically don't have any sources of information as to where they can find the desired crops.

Succeeding in rising agricultural profits, inputs and outputs must be balance which is fundamental. GIS is equipped with great ability to analyze and visualize agricultural activities and workflow has turned out evident to those in farming industry. Although natural inputs in agriculture cannot be controlled, they can easily be interpreted using GIS applications such as global estimation of crop productivity (Tan and Shibasaki 2003), National spatial crop yield simulation (Priya and

Shibasaki, 2001) and erosion identification and remediation (Pandey, Chowdary and Mal, 2007).

1.2 Purpose

The main objective of this thesis was to develop a spatial-temporal agricultural information system to optimize pesticide usage by creating a buffer-zone. The system will collect both spatial and non-spatial data about pesticide used on various crop fields by farmers. In addition, the collected data will determine how long a spray drift can move beyond the target area after or during pesticide application. Ultimately this will provide timely and accurate information and reports on pesticide usage incidences, that impact on the lives and property of the public, and institutions. Below are system inputs

1.3 GIS for Agriculture

A GIS is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data from different historical periods and at various scales of analysis (Mitchell, 1999). More important, GIS is about geography and learning about the world in which we live. As GIS technology develops, as society becomes ever more geospatially enabled, and as more and more people rediscover geography and the power of maps, the future uses and applications of GIS are unlimited. By applying GIS technology, agricultural operations are able to manage resources and responsibilities more efficiently, devise data portals that disseminate vast amounts of agricultural data and interactive maps, and support farming communities. The powerful analytical capabilities of GIS offer an array of options for visualizing farming conditions, as well as measuring and monitoring the effects of farm management practices. GIS can be used to precisely determine and control inputs, saving preventive expense and reducing the amount of harm to the crops. Pesticides used in agriculture may cause adverse effects among other crops adjacent of planted near target areas. However, identifying these areas most likely to be exposed is difficult. Agricultural crop fields can be represented using GIS. This can easily show the closeness among crop fields. This study demonstrates that spatial records of crop field location can be used to create crop maps. Using a GIS, zones of potential exposure to agricultural pesticides and closeness measures can be determined.

1.3.1 Characteristics of GIS

With software, you can digitally represent geographic objects with a variety of shapes and layer those shapes on top of one another to create maps and perform analysis.

- Polygons
- Lines
- Points

1.3.2 Types of Data Types in GIS

There are two major families of GIS Data

1.3.2.1 Raster Data

Cell-based raster data sets (images and grids) are especially suited to representing traditional geographic phenomena that vary continuously over space such as elevation, slope, and precipitation. They can also be used to represent less traditional types of information such as population density, consumer behavior, and other demographic characteristics. Rasters are also the ideal data representation for spatial modeling and analysis of flows and trends over data represented as continuous surfaces such as hydrologic modeling or the dynamics of population change over time.

1.3.2.2 Vector Data

Vector data provide a way to represent real world features within the GIS environment. A feature is anything you can see on the landscape. Imagine you are standing on the top of a hill. Looking down you can see houses, roads, trees, rivers, and so on.

1.4 Role of GIS

Geographic Information System (GIS) is rooted in intellectual practices, populated by data and powered by mathematical analysis. A survey conducted by Schuurman (2004) suggested that currently, the main use of GIS is for spatial analysis, predictive modeling, cartography and visualization. The SI Industry, also known as the GIS industry, is a rapidly growing industry. GIS maps the exact location and survey coordinates of an object in space to provide answer to queries using a computer system (Ibid, 2004).

Furthermore, Monroe County (2008) defines the GIS as a mapping tool for mapping visualisation and geographic analysis. “Geographic Information Systems are computer based tools for mapping and analysing features and events on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualisation and geographic analysis benefits offered by maps” (Monroe County, 2008).

Thus, the use of GIS is needed to collect data, store, manage, analyze and produce useful information. In other words, the process of GIS is to input sets of raw data to produce useful output information. CAS relies on the input of accurate historical records and utilizes the functionality of GIS to produce predictions and response plans for this natural phenomena.

A function of GIS is the ability to query databases using a selection of attributes or selection of locations for special criteria to find the relationships between different results, as shown in Table 2.1. Hence, GIS draw upon analysis models in the quantitative method. Therefore, spatial analysis for the project requires the understanding of quantitative data calculations in order to create meaningful implementation.

Table 1.1 Selections by Attributes and Selection by Location.

Select by Attributes	Select by Location (graphical selection)
Using formulas and functions	Using geographical content
Satisfies the included region using	Satifies the included region using location
Both use mathematical and statistical functions	
Both show results in geographical and table content	

Initial use of GIS was for cartography and mapping. However, the methods of computerizing cartographic procedures were coincident with the realization that mapping could be used in analysis through overlays and calculations (Schuurman, 2004). Nowadays, the analytical technique in GIS is known as spatial analysis,“Spatial analysis is differentiated from ‘mapping’ because it generates more information or knowledge that can be gleaned from maps or data alone” (Ibid, 2004).

1.5 Spatial Analysis

Spatial analysis involves the overlapping of different characteristics of datasets, known as map overlays. Map overlay, as illustrated in Figure 2.1, made up of collections of similar geographic objects, also known as features, arranged in layers. It is through the overlay technique, that the result of the analysis can be understood, for example Monroe County (2008). Every feature in a GIS map is connected to a spatial table in the overlay. The table is filled with attributes of data that could be examined as information (Ibid, 2008).

Figure 1.1 Data and information comes from a set of layers.

Furthermore, GIS divides the world into objects and attribute tables (ESRI, 2008; Geoscience Australia, 2008), both of which can be represented spatially by raster or vector datasets which are shown on the map overlay:

- Raster dataset that comes from grids, e.g. images, aerial photos.
- Vector dataset that comes from mathematical calculations and functions, e.g. points, lines, polygons.

Both types of dataset will be used to produce complete and extensive data in the Area of Study.

GIS also has programming capabilities, however, in this thesis the programming is limited to simple and complex queries in MYSQL and PHP. As a result, simple map algebra and calculation functions can be achieved. Therefore, the main tool for CAS involves visualization and analysis using GIS.

The rest of this thesis is organized as follows. Section 2 discusses some related work. Section 3 introduces conceptual spatial-temporal agricultural data model. Sections 4 presents research methodology. Overview of spatial-temporal agricultural conceptual model. Section 5 presents system implementations. Section 6 concludes the thesis and points to directions for future research.

CHAPTER TWO
LITERATURE REVIEW

2.1 UML Modeling for Geographic Data

In order to improve the efficiency of agricultural processes, many investments are being made in this area. Zhang et.al., (2001) developed a field-level geographic information system (FIS) that provides special analytical functions useful for research in precision farming in (Zhang, Runquist, Schrock, Havlin, Kluitenburg and Redulla, 1999). They integrated spatial data from various sources with different accuracies and resolutions. In addition, a discrete model was developed to simulate the time lag inherent to a yield sensor on a combine harvester in the same research. Pinet et.al proposed a language for expressing complex spatial constraints and improved UML models using geographical type constraints and topological constraints in (Pinet, Kang and Vigier, 2005). They also presented in-depth experiments in the domain of agricultural information systems. (Filho and Iochpe, 2008) extended UML with new elements that enable the modeling of spatial–temporal characteristics of geographical phenomena and generated a profile of stereotypes to support the GeoDB conceptual modeling. (Mennis and Guo, 2009) reviewed spatial data-mining tasks, including spatial classification and prediction; spatial association rule mining; spatial cluster analysis; and geo-visualization. They also summarized articles contribute to spatial data mining research by developing new techniques for point pattern analysis, prediction in space-time data, and analysis of moving object data, as well as by demonstrating applications of genetic algorithms for optimization in the context of image classification and spatial interpolation.

Precise farming is a knowledge-based system that integrates many advanced information technologies that enables farmers to apply precise amounts of fertilizers, pesticides, water, seeds or other inputs to specific areas where and when they are needed for optimal crop growth. Zhang et al., (2002) is an excellent reference for natural-resource variability, impact of precision-agriculture technologies on farm profitability and environment, innovations in sensors, controls, and remote sensing, applications and adoption trend of precision-agriculture technologies. Lu, Daughtry, Hart and Watkıns, (2008) reviews the current state of the art of precision farming and its major components, and discusses economic feasibility and potential implications for agricultural structure and rural communities. (Ruß & Brenning, 2010) presents a spatial cross-validation data mining technique to overcome yield prediction task in-season using available geo-coded data sets.

2.2 Data Mining in Agriculture

Data mining in application in agriculture is a relatively new approach for forecasting/predicting the proper pesticide usage and the crop yield in advance for market dynamics. Abdullah et al., (2004) showed how data mining integrated agricultural data including pest scouting, pesticide usage and meteorological recordings is useful for optimization of pesticide usage. Their work is on pesticide usage through Data Mining, unlike this study which is related with spatial-temporal information system. Oakley, Zhang and Miller, (2007) reported on findings of research project to capture differences in pest management strategies and decision-making among growers using the California Pesticide Use Reports database. They have found large variations in pesticide use, low numbers of fungicide and herbicides users in the researched area.

CHAPTER THREE
SPATIAL TEMPORAL MODEL

3.1 Overview of the Spatial-Temporal Agricultural Conceptual Model

A spatial database management system (SDBMS) provides storage structures and basic operations for spatial data manipulation, whereas geographic information systems (GIS) provide the mechanisms for analysis and visualization of geographic data (Shekhar and Chawla, 2003). In this way, geographic databases (GeoDB) are collections of georeferenced spatial data, stored by SDBMS and manipulated by GIS (Borges, Davis and Laender, 2001). GeoDB must be designed following methodology that includes the conceptual, logical and physical design phases. It has been acknowledged for several decades that conceptual models allow describing the requirements of an application in terms that are as close as possible to users' perception.

A GeoDB stores three large data categories: convetional data without geographic reference (e.g., product), geographic phenomena perceived in object view (e.g., cities, farms), and geographic phenomena perceived in field view (e.g., temperature). The main UML-GeoFrame contribution consists of providing a construct group that enables the designer to carry out the modeling of geographic phenomena perceived in field view appropriately (Filho and Iochpe, 2008). Therefore, the UML-GeoFrame uses the same constructs of UML class diagram, such as classes and subclasses containing attributes and operations, and associations between classes, also enabling the specification of aggregation and composition (Rumbaugh, Jacobson and Booch, 2004).

3.2 Requirements for Modeling Geographic Data

This section describes requirements for modeling geographic data in terms of the spatial characteristics this type of data has. The following aspects are to be considered about objects in geographic data models:

Location and extent. The spatial location and extent is defined by x, y and z coordinates in a specific reference system. This is always defined by coordinates pairs of data source, for instance the latitude and longitude of Buca, county of Izmir-Turkey, are shown in Figure 3.1 below. ***Latitude***: 38.3854789, ***Longitude***: 27.174709.

Figure 3.1 Shows the representation of a location and extent.

Thematic values. An object has several attributes that define the thematic characteristics. For example, value classification where all objects have the same value, unique symbol where all objects have same appearance. This is designed to show a particular theme connected with a specific geographical area. This can be shown in Figure 3.2 below where farms are represented by polygons.

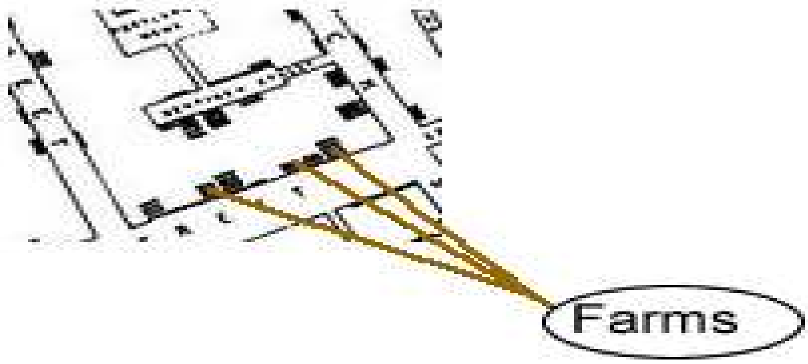


Figure 3.2 Farming areas represented by specific geographic feature.

Temporal Extent. It is necessary to keep track of and record an objects existence and change in time. Transaction time is the time when an object is stored in a database and valid time is the time when an object is true and exists in the real world. An example is shown in the Figure 3.3 below.

Figure 3.3 Representation of a temporal extent.

Entity- vs. field-based data. Entity based describes the world as a space that is filled with discrete, identifiable units (i.e., objects) that have some sort of spatial reference, usually in the form of geographic coordinates. For example, some objects you might find in this space could include: houses, factories, roads, rivers, lakes, or pollution plumes. A field-based model on the other hand, describes the world as a collection of spatial distributions of phenomena. In other words, for a particular attribute or theme we are interested in (e.g., elevation or temperature). It is important to be able to distinguish between entity and field based data, because they have fundamentally different characteristics.

Geographic structure. Geographic class instances are objects having a specific attribute named geometry. A class that specializes a geographic class is also geographic. A stereotype <<geographic>> is associated to each geographic class. One, two, and three-dimensional structures of geographic features should be possible with points (and multi-points), lines (and multi-lines), polygons (and multi-polygons), rasters, etc. When using the multi representation it means that an 365 object is represented by more elements (e.g. a building consists of two polygons). Example can be seen in the Figure 3.4 below.

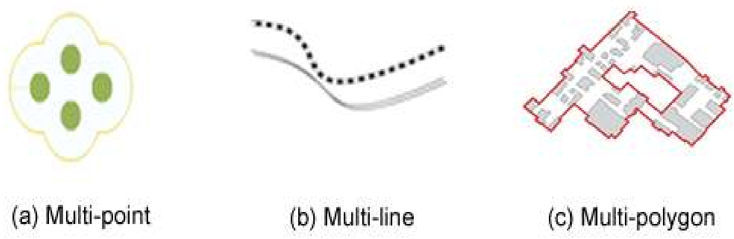


Figure 3.4 Shows the representation of geographic structure where (a) represents multipoints, (b) represents multilines and (c) represents multipolygons.

Object id. A unique object id is necessary for exchange purposes. When different institutions and authorities need to exchange data, a help in this process would be to ensure a unique identity of objects. This can be seen in the Figure 3.5 below.

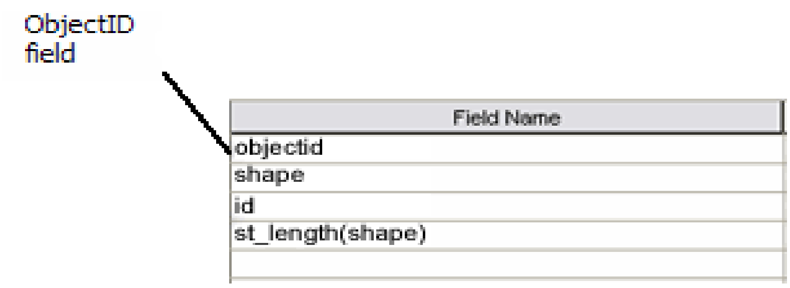


Figure 3.5 Shows representation of an object id.

Roles. An aspect, which is closely related to the representation, is the role of an object. A geographic object can be defined differently depended on the universe of discourse, in other words a role is application depended.

CHAPTER FOUR
METHODOLOGY

4.1 Overview

This section discusses the methods that the researcher has used to collect and evaluate the data in accordance to the goal of the study. The data collected involves both spatial and non-spatial data about pesticide used on various crop fields by farmers. In addition, we collected data that determines how long a spray drift will move beyond the target area after or during pesticide application. Below is the brief overview of various data that was used to accomplish our objective of this thesis.

4.2 Spatial Data

This is data that define a location. These are in the form of graphic primitives that are usually either points, lines, polygons or pixels. Spatial data includes locations, shape, size and orientation. For example, consider a particular square:

- its center (the intersection of its diagonals) specifies its location
- its shape is a square
- the length of one of its sides specifies its size
- the angle its diagonals make with, say, the x-axis specifies its orientation.

4.3 Non-spatial Data

This is data that relate to a specific, precisely defined location. The data are often statistical but may be text, image or multi-media. These are linked in the GIS to spatial data that define the location. Non-spatial data (also called *attribute* or *characteristic* data) is that information which is independent of all geometric considerations.

- For example, a farm's id, owner, and soil type are non-spatial data because they are independent of the farm's location.

It's interesting to note that, while mass is non-spatial data, weight is spatial data in the sense that something's weight is very much dependent on its location.

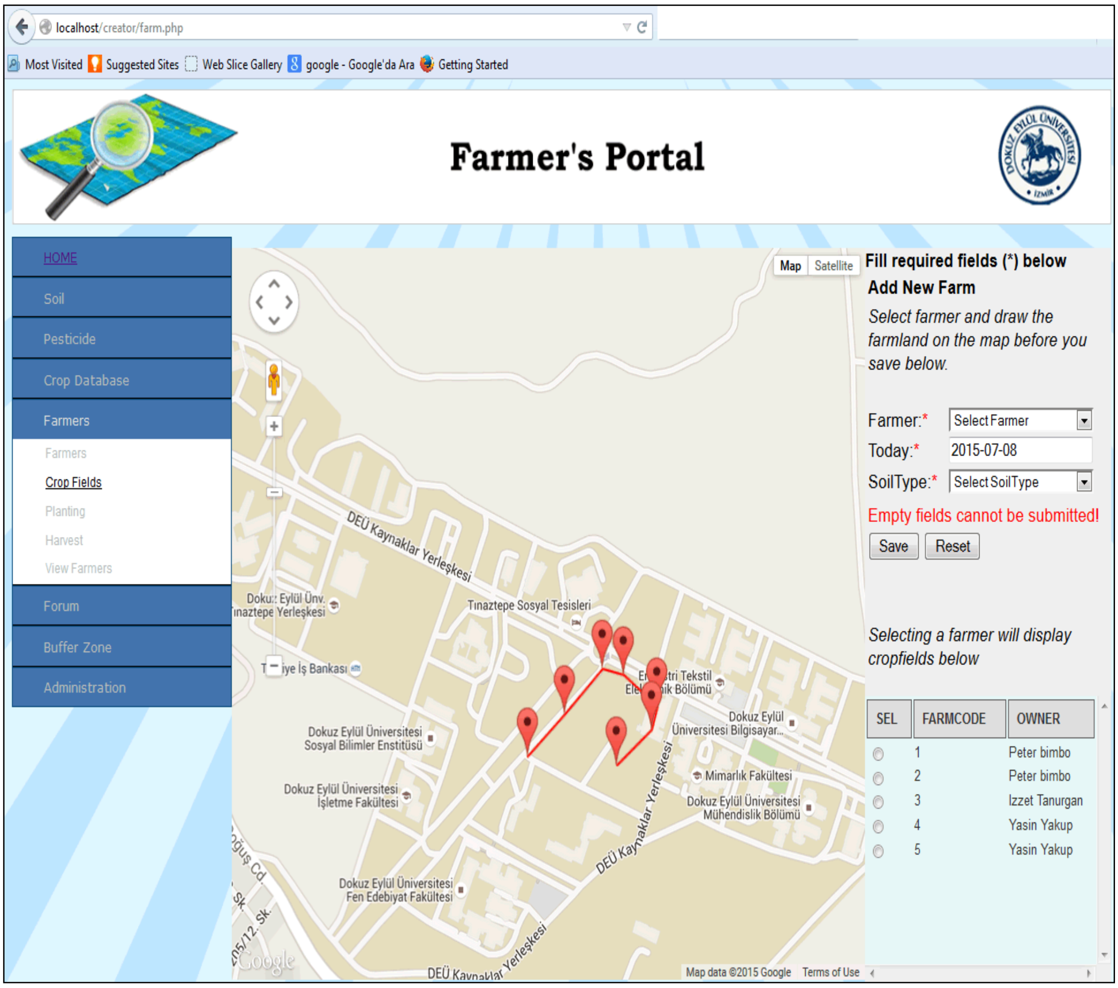
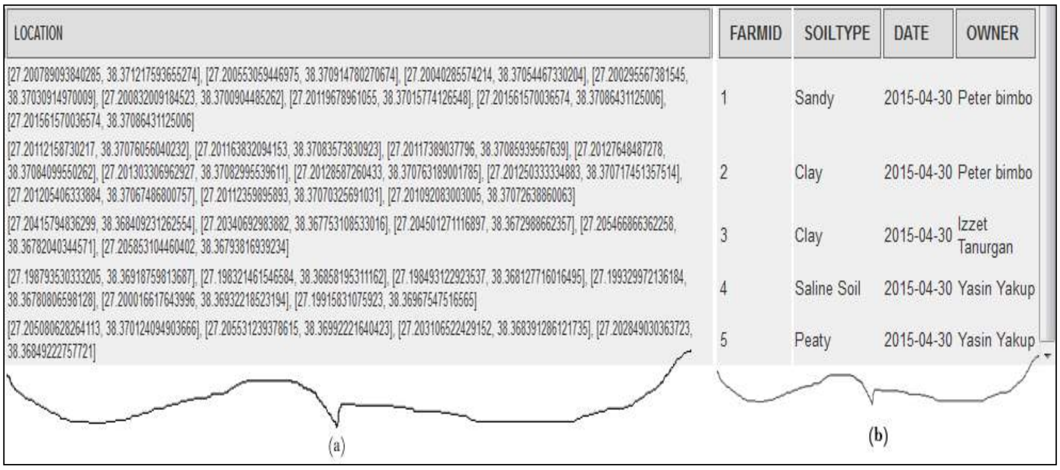


Figure 4.1 Demonstrates a tool used to collect both spatial and non-spatial data.



LOCATION	FARMID	SOILTYPE	DATE	OWNER
[27.200789093840285, 38.371217593655274], [27.200553059446975, 38.370914780270674], [27.20040285574214, 38.37054467330204], [27.200295567381545, 38.37030914970009], [27.200832009184523, 38.3700904485262], [27.20119678961055, 38.37015774126548], [27.201561570036574, 38.37086431125006], [27.201561570036574, 38.37086431125006]	1	Sandy	2015-04-30	Peter bimbo
[27.20112158730217, 38.37076056040232], [27.201163832094153, 38.37083573830923], [27.20117389037796, 38.37085939567639], [27.20127648487278, 38.37084099550262], [27.201303306962927, 38.37082995539611], [27.20128587260433, 38.370763189001785], [27.201250333334883, 38.370717451357514], [27.201205406333884, 38.37067486800757], [27.20112359895893, 38.37070325691031], [27.201092083003005, 38.37072638860063]	2	Clay	2015-04-30	Peter bimbo
[27.20415794836299, 38.368409231262554], [27.20340692983882, 38.367753108533016], [27.204501271116897, 38.3672988662357], [27.205466866362258, 38.36782040344571], [27.205853104460402, 38.36793816939234]	3	Clay	2015-04-30	Izzet Tanurgan
[27.198793530333205, 38.36918759813687], [27.198321461546584, 38.36858195311162], [27.198493122923537, 38.368127716016495], [27.199329972136184, 38.36780806598128], [27.200016617643996, 38.36932218523194], [27.19915831075923, 38.36967547516565]	4	Saline Soil	2015-04-30	Yasin Yakup
[27.205080628264113, 38.370124094903666], [27.205531239378615, 38.36992221640423], [27.203106522429152, 38.368391286121735], [27.202849030363723, 38.36849222757721]	5	Peaty	2015-04-30	Yasin Yakup

Figure 4.2 (a). Demonstrates spatial data as a physical representation of a polygon or crop field on the earth's surface, while (b) shows non-spatial data that is a metadata of a polygon or crop field on the earth's surface.

4.4 Spray Drift Dynamics

Spray drift has become an important aspect and can be defined as the amount of product that comes directly from the nozzles and is deflected out of the treated area by the action of air flow. Spray drift and the size of non targeted area affected by drift and its severity depend on how adverse the weather conditions are and poor decisions made by the operator of the sprayer. As liquid emerges through the nozzle at high discharge speed, it is quickly breaks into parts or droplets. Large droplets are not as likely to drift as smaller droplets. The droplets have enough inertia for them to be effective in transferring momentum, matter and heat. The high inertia also causes the ambient air to be dragged into motion, which may either be one of the primary functions of the sprays or may have an important effect on its performance. In the vertical sprays that are high enough above the ground, the inertia of the droplets is determined by their weight (or buoyancy forces) than initial momentum and eventually they can reach their terminal velocity (Ghosh and Hunt, 1994). Figure 4.3 below displays basic spray drift dynamics.

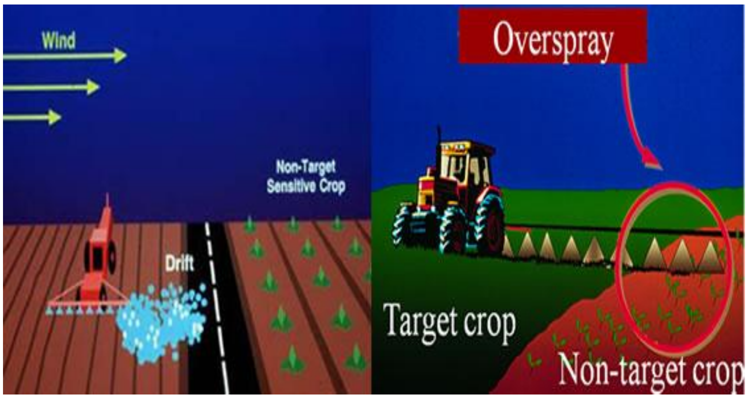


Figure 4.3 Spray drift dynamics that take place during pesticide application

4.4.1 Factors that Influence Spray Drift

This is the distance the spray particles or vapor will move horizontal or parallel to the earth's surface. Unfortunately, when applying pesticides there is a chance that some will escape from the target area to sensitive areas (non-target areas). This occurs as a result of the following factors;

a) Droplets

Actually, the larger they are, the closer they fall. Smaller droplets fall through the air slowly and are carried farther by air movement. The size of the droplet is measured in microns. Droplets with diameter smaller than 100 microns, about the diameter of a human hair, are considered highly driftable and are so small they cannot be readily seen unless in high concentrations, such as fog. As a result of smaller size, drift is more dependent on the irregular movement of turbulent air than on gravity. Various sizes of droplets from small to larger sizes are illustrated in Figure 4.4.

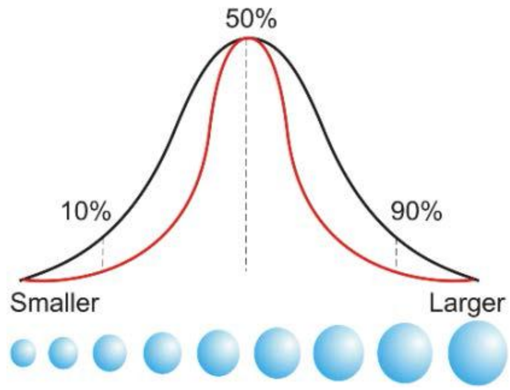


Figure 4.4 Various sizes of droplets from small to larger sizes.

Table 4.1 below shows the effect of droplet size on the rate of fall (Grisso, et al., 2013). The longer the droplet is airborne, the greater the potential for drift. When leaving the nozzle, the solution may have a velocity of 60 feet per second (41 mph) or more. Unless the spray particles are electrostatically charged, there are two forces acting upon the emerging droplets. These forces, gravity and air resistance, greatly influence the deceleration and movement of spray droplets. Droplet speed is reduced by air resistance, which can also break up the droplets. After their initial speed slows, the droplets are more influenced by gravitational pull.

Table 4.1 Effect of droplet size on drift potential.

Droplet Diameter (microns)	**Droplet Size**	**Time Required to Fall 10 Feet**	**Lateral Movement in a 3-mph Wind**
5	Fog (VF)	66 minutes	3 miles
20	Very fine (VF)	4.2 minutes	1,100 feet
100	Very fine (VF)	10 seconds	44 feet
240	Medium (M)	6 seconds	28 feet
400	Coarse (C)	2 seconds	8.5 feet
1,000	Extremely coarse (XC)	1 second	4.7 feet

b) Spray height

Spray height is the most significant variable in the prediction equation for spray drift (Bode, Butler and Goering, 1976). Wind speed is usually greater as nozzle height above the ground increases. A statistical significant difference was noted in the reduction of spray drift for 54% when the boom height is decreased from 70 to 50 cm (Jong , Michielsen , Stallinga and Van de Zande, 2000). According to the results of Nuyttens et al., (2007) lowering the spray nozzle height from 50cm to 30cm significantly decreased the amount of spray drift 40.1%. (Miller et la., 2008) showed that increasing of the nozzle height from 50 to 70 cm increased the airborne spray volume measured at 2.0 m downwind by a factor of approximately four. In aerial application, several sprays were carried out including effect of spray boom height on spray drift, the spraying results indicated that the lower drift had generated at lower release heights (Teske and Thistle, 1999) and any increasing in the release height affects spray deposition and off-target drifts (Barbosa, 2010). In general, nozzle height must be at optimum level according to nozzle characteristics for decreasing spray drift risk (Arvidsson, 1997; Miller, 1999). With lower boom heights, the initial speed may be great enough that the droplet reaches the target before drift occurs. Large droplets maintain a downward velocity longer than smaller ones, and are more likely to deposit on the intended target. Small droplets evaporate quicker than larger droplets, leaving minute quantities of pesticide in the air.

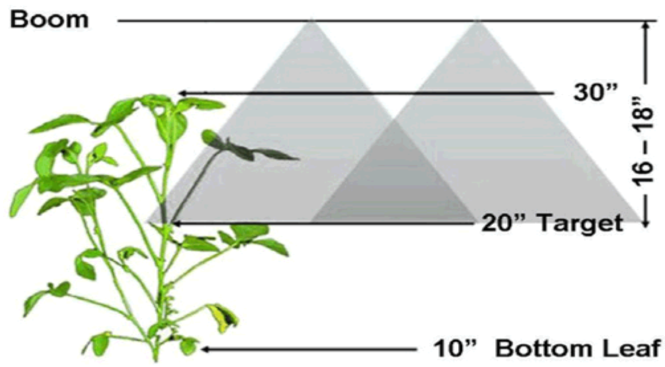


Figure 4.5 Shows the vertical level at which spray droplets are being released to the crops, this can be adjusted depending on the height of crops

c) Driving speed

During the spraying process, increasing of the driving speed increases spray pressure and air flow around the spray, leads to the smallest droplets escape from the spray and falling far away from the target, resulting in a higher amount of drift (Ghosh and Hunt, 1998). (Miller and Smith 1997) found that an increase in forward speed from 4 to 8 kmh-1, airborne spray drift increase of 51% and when the speed was further increased to 16 km h-1, airborne spray drift increased 144%. In aerial application, local forward speed plays an important role in controlling the drift potential: the higher the forward speed, the greater the spray drift because the performance of hydraulic nozzles is affected by air shear; as airspeed increases, so does air shear that shatters the large droplets resulting in increasing the percentage of the fine droplets and turbulence (Barbosa, 2010; Akesson, 1989; Kirk, 2002).

d) Cross Wind speed

This is caused by air moving from high pressure to low pressure, usually due to changes in temperature. Both the amount of pesticide that is lost from the target and the distance it travels increases as wind velocity increases. However, drift injury can occur with low wind velocities. Spray distribution and drift depend on wind speed during the time of application. In a weak crosswind, small droplets from the nozzle tend to aggregate towards the spray centerline. While in a strong cross-wind; small droplets cannot resist the strong air flow because of their low inertial energy, making them highly susceptible to the drift (Ghosh and Hunt, 1998). In the field, weather conditions are different from one place to another, change from time to time and it is not easy to control them during testing operation, therefore, some spraying applications were carried out at wind speed varied from 0.3 to 1.8 ms-1 (Bjugstad and Hermansen, 2009). Bahrouni et al., (2010) noted that during the spraying process, important pesticide amounts are transferred to the environment by wind.

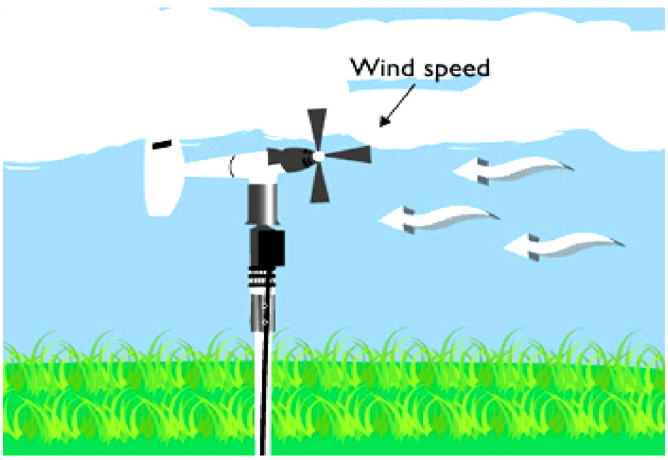


Figure 4.6 Shows an anemometer tool that is commonly used to measure wind speed.

e) Wind Direction

This is reported by the direction from which it originates. For example, a *northerly* wind blows from the north to the south. Wind direction is usually reported in cardinal directions or in azimuth degrees. For example, a wind coming from the south is given as 180 degrees; one from the east is 90 degrees.

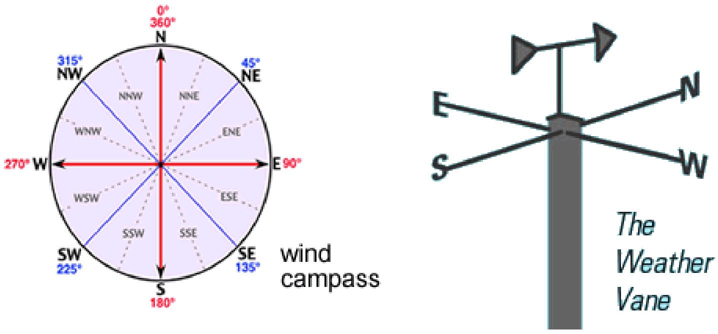


Figure 4.7 Shows tools used to measure the direction of wind such as the windsock and wind vane.

f) Gravity

This is the force that acts on objects in a direction that is perpendicular to level ground. This means that, if an object is moving parallel to the ground, the force of gravity is only pulling on the object in a downward direction.

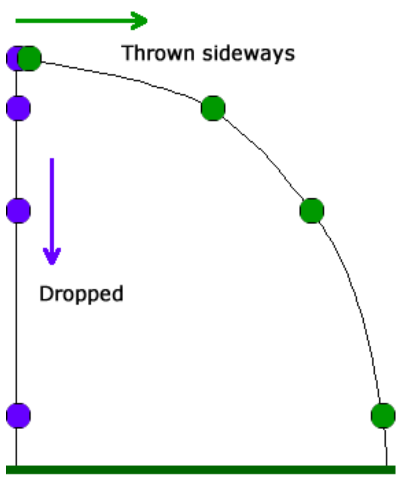


Figure 4.8 Shows an object dropping downwards without any force being applied to it and the other one with force being applied

4.5 Calculating Spray Drifts Distance

This section will discuss the formula that was used to calculate spray drift distance. This is the length or space spray drifts can move from target area to sensitive (non-target) area. To achieve this, a derivation of equation for displacement was used (Kurtus, 2011). You can find the displacement an object projected sideways from the following derivation. First, consider the standard displacement-velocity equation:

$$\mathbf{x = v_s t}$$

where

- **x** is the horizontal displacement in feet (ft) or meters (m)
- $\mathbf{v_s}$ is the initial sideways or horizontal velocity in ft/s or m/s
- **t** is the time until the object hits the ground in seconds (s)

The equation for the time a falling object takes is:

$$\mathbf{t = \sqrt{(2y/g)}}$$

where

- **y** is the displacement the object has fallen from its starting point in *m* or *ft*
- **g** is the acceleration due to gravity (32 ft/s^2 or 9.8 m/s^2)

Thus, the displacement the object travels, as a function of the initial velocity and the height is:

$$\mathbf{x = v_s\sqrt{(2y/g)}}$$

This experiment of sideways motion is illustrated in the diagram below.

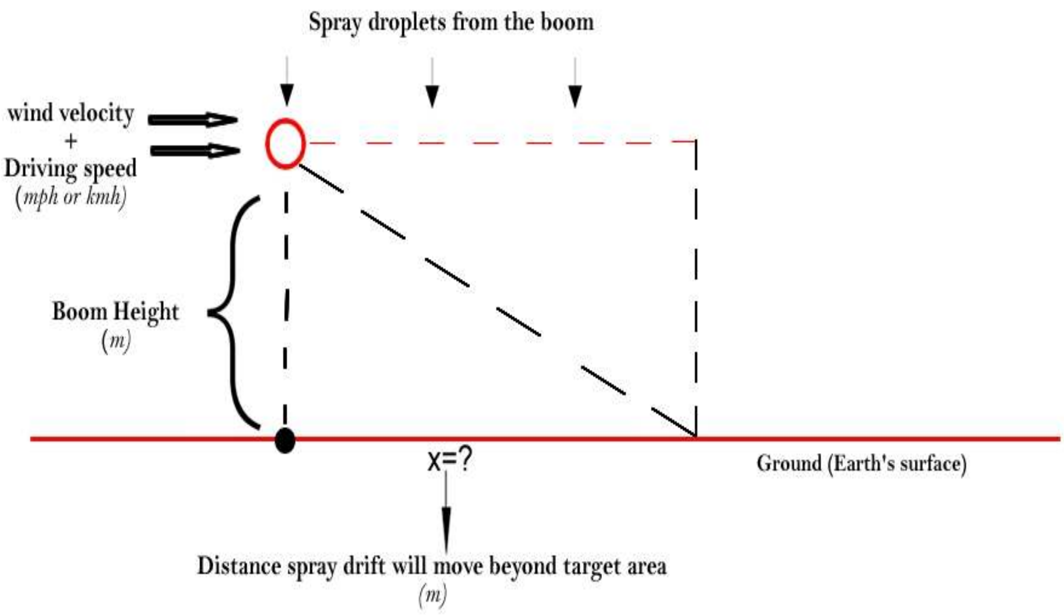


Figure 4.9 Shows the procedures undertaken to determine the distance a spray drift can move while certain forces are being applied.

From the Figure 4.9 above, you can see a simple experimental design to verify this phenomenon. A spray droplet is released from the boom at a specific height above the sea level, while the wind force or velocity is applied behind it. Due to this velocity, spray droplets are forced to break and this enable them to be driven away from target area, thus providing us the required distance to establish a 'buffer zone' around the perimeter of each application block where pesticide is applied.

Table 4.2 Shows synthetic data obtained using our methodology which includes data about wind speed, driving speed, boom height, gravity and finally spray drift distance.

Wind speed(mph)	**Driving speed(mph)**	**Boom height(m)**	**Gravity (m / s^2)**	**Drift Distance(m)**
5	8	3	9.8	**10.17**
6	7	3	9.8	**10.17**
8	6	3	9.8	**10.95**
10	5	3	9.8	**11.74**
16	4	3	9.8	**15.65**
19	3	3	9.8	**17.21**

When a spray application is carried out in the direction of wind, then wind directions factors remains zero inother words it will not affect the process therefore the process can continue. On the other hand, when wind direction changes against the intended direction then we advise not to spray until the situation stablizes.

CHAPTER FIVE
RESEARCH IMPLEMENTATION

5.1 Overview

This section includes the description of all stages involved in the implementation of our farming information management system. To analyze the buffer zone, a simulation was used to simulate the distance a spray drift can be moved during pesticide application on crops. Distance simulation requires data entries about wind speed, driving speed, boom height and gravitational forces. The simulation uses a derivation of equation for displacement to calculate the distance in meters. Steps for completing a simulation Project are as follows:

5.2 Functions of the System

Our system has three basic functions:

- **Input**: Something must go into the system; otherwise, it is a mysterious sphere where products or services mystically radiate from it. As noted below, the basic inputs of our system are spray height, driving speed, wind speed, wind direction, and gravity.
- **Process**: Some type of work must be accomplished in the system. This work is the technology performed that changes the material input into the system's output.
- **Output**: A desired service or product must be produced. If there is no output, then it is a black hole where things go in, but nothing emerges. Our targeted output will be spray drift distance. This will enable us to determine the buffer zone required to absorb pesticide drifts.

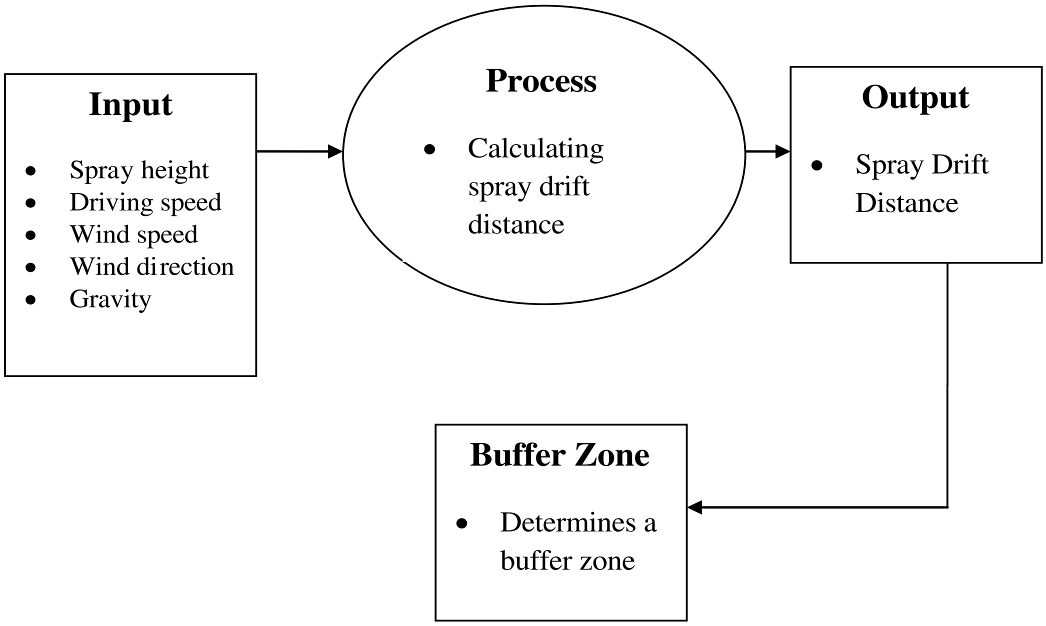


Figure 5.1 Shows functions of the system.

5.3 System Design

The design of our farming information management system was conducted in the following ways:

Detailed conceptual models are necessary, when developing systems for geographic information to ensure consistency and integrity (Friis-Christensen, 2001). Geographic data have many common properties such as location and extent, which are not supported in the standard modeling languages, like the Unified Modeling Language (UML) or the Entity/Relationship (E/R) model. Since there is no standard way of modeling geographic data, models describing the same phenomena could be designed and interpreted differently. In this thesis the object-oriented modeling language, UML, is used. UML is chosen as the modeling language because it has become widely used both in academia and in the industry.

UML for GeoDB was used for process modeling. A spatial database management system (SDBMS) provides storage structures and basic operations for spatial data manipulation, whereas geographic information systems (GIS) provide the mechanisms for analysis and visualization of geographic data (Shekhar and Chawla, 2003). In this way, geographic databases (GeoDB) are collections of georeferenced spatial data, stored by SDBMS and manipulated by GIS (Borges, Davis and Laender, 2001). GeoDB must be designed following methodology that includes the conceptual, logical and physical design phases. It has been acknowledged for several decades that conceptual models allow describing the requirements of an application in terms that are as close as possible to users' perception.

A GeoDB stores three large data categories: conventional data without geographic reference (e.g., product), geographic phenomena perceived in object view (e.g., cities, farms), and geographic phenomena perceived in field view (e.g., temperature). The main UML-GeoFrame contribution consists of providing a construct group that enables the designer to carry out the modeling of geographic phenomena perceived in field view appropriately (Filho and Iochpe, 2008). Therefore, the UML-GeoFrame uses the same constructs of UML class diagram, such as classes and subclasses containing attributes and operations, and associations between classes, also enabling the specification of aggregation and composition (Booch, Jacobson and Rumbaugh, 2004).

5.4 Spatial-Temporal Conceptual Model

This section presents the steps that followed during the Spatial-Temporal GeoDB modeling process. We used GeoFrame (Filho and Iochpe, 2008) package to construct model themes. This allows the designer to focus on a specific theme at a time to carry out data modeling. Additionally, multiple spatial representations, spatial relationships and temporal aspects are also easily specified using the UML-GeoFrame. Our case study focuses on a particular agricultural area in Izmir, Turkey.

Landparcels can have agricultural use or be buildings; however we only kept agricultural use for the sake of the simplicity. Farm lands owners' (SSN and name is known), who may change in time, and their geometries in space are recorded in the database. For farm lands, soil type, vegetation, and elevation are recorded; the first two in terms of regions, while the last one in terms of points. The UML diagrams below correspond to the modeling of object classes related to the implementation of buffer zone calculator inside a Geographic information system. These class diagrams explain the application area of interest and the theme classes, describing the several themes that will portray this area.

Spatial objects have a position in space, and it is frequently necessary to capture this position in the database. Spatial Object generalizes the classes of spatial representation of geographic phenomena in object view, such as **Point**, **Line**, **Polygon** or **ComplexSpatialObject**, which recurrently consists of two or more spatial objects. The spatial relationship set "is located at" that associates a spatial entity set with its geometry. The cardinality of this set is 1:M, meaning that a spatial entity may have more than one geometry when multiple granularities are employed. When geometry is connected to space then it captures also the locations of objects. In this case, GEOMETRY describes objects positions, i.e., shapes and locations (David, Herrewegen and Salge, 1996).

A Geographic object in a triangle in the upper-right corner of an entity set rectangle specifies the spatial support. A spatial association with entity "country" is represented by a spatial object of polygon type as shown in Figure 5.2 (a). The spatial entity set "country" with geometry polygon type is illustrated in Figure 5.2 (b). For instance, as depicted in Figure 5.3, a country has the spatial characteristic of a region/polygon, while a city and district have the characteristic extension in form of a point.

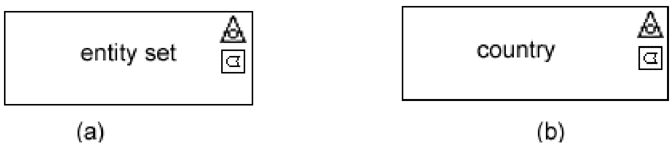


Figure 5.2 (a) Spatial entity sets, (b) a farmland as POLYGON.

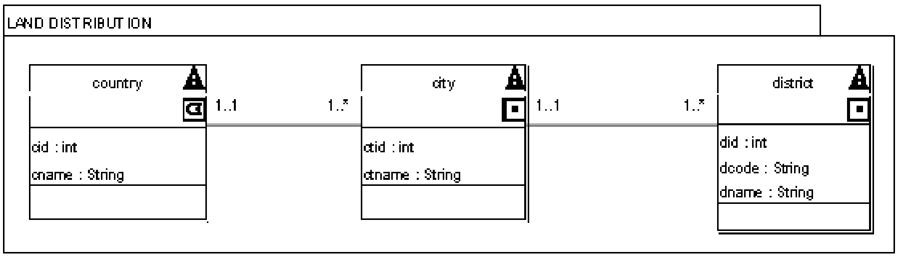


Figure 5.3 Land distribution theme diagram.

Entities in an entity set can be assigned existence and transaction time. We term the former support for valid time, and this is indicated by placing "temporal" icon in the upper let corner of the entity set's rectangle as indicated in Figure 5.4 (a). Figure 5.4 (b) shows the conventional "pesticideusage" entities, that we keep track of their valid time. This notation is in effect shorthand for a larger UML diagram. This shorthand is convenient because it concisely states that the valid times of the entities in the entity set should be captured in the database.

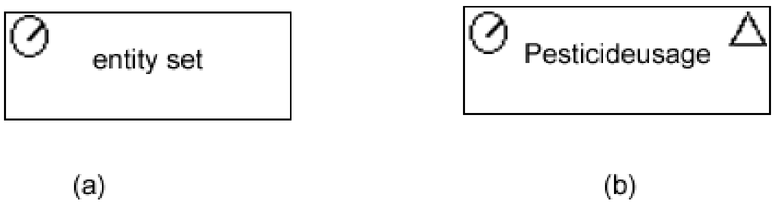


Figure 5.4 (a) Capturing valid time, and (b) representing pesticideusage entities and their valid times.

For a geo-referenced object, GEOMETRY captures both its shape and location. When an object changes its position over time, i.e., the object moves (change of location) or the object changes shape, it is the GEOMETRY aspect of the object that changes rather than the object itself. For example, a crop field may change its shape as time goes on, but this is not considered to change the owner's identity. To capture a spatiotemporal aspect of the objects in an entity set, polygon feature is placed in the upper-right corner of the entity set's rectangle and then a temporal feature is palced in the upper-left hand corner. The captures valid-time of the objects' current positions as well as their past and future positions are to be captured. This is illustrated in Figure 5.5 (a). Figure 5.5 (b) shows that, when a "farmland" changes product we record both the farm's position in time and the time this is recorded in the database (i.e., "valid and transaction time"). The geometric type of the entity set is known, represented by a POLYGON.

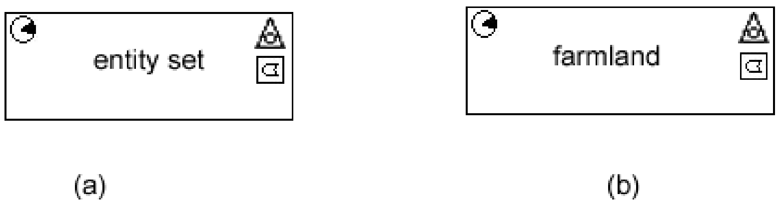


Figure 5.5 (a) A spatiotemporal entity set with valid-time support, (b) recording farm position with valid-time and transaction-time support given in.

Figure 5.6 below illustrates the farmer theme containing two classes; farmer and farmland. For instance, farmer class shows that it has a spatial characteristic of a point. While farmland shows that it has a spatial characteristic of a polygon as well as a spatiotemporal of interval type. Each time a property of the farmland class is changed, a new version of object farmland will be created.

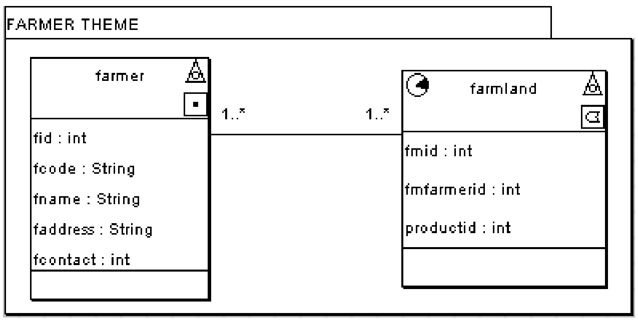


Figure 5.6 Shows farmer theme diagram.

Figure 5.7 below illustrates the supplier theme containing two classes; supplier and pesticide purchase. For instance, supplier class shows that it has a spatial characteristic of a point. Pesticide purchase is a conventional object with spatiotemporal element of instant type. Each pesticide purchase made generates a new object instance that contains data recording purchase valid time (e.g., date or year).

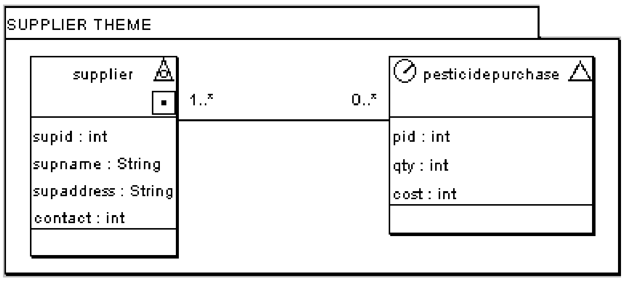


Figure 5.7 Supplier theme diagram.

Finally, the partial conceptual schema for spatial-temporal agricultural information system depicted in Figure 5.8 below, UML-GeoFrame diagram which describes our GIS project in this research.

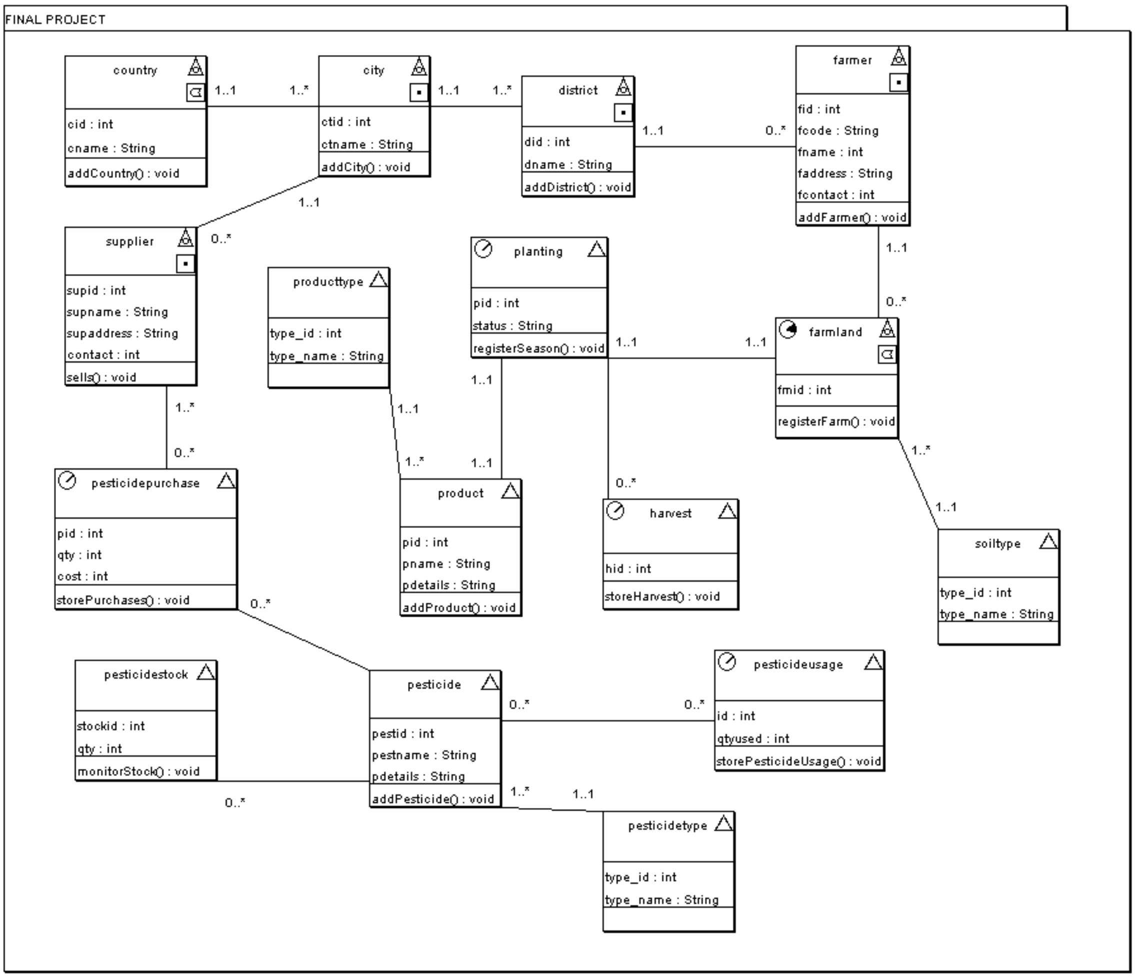


Figure 5.8 The partial conceptual schema of a spatial-temporal agricultural information system.

In our work, we have basically chosen UML because this language became Standard method to model information systems. This provides a precise constraint representation of complex geometries and has emerged to improve the efficiency of systems analysts and the quality of spatial database design.

5.5 Entities and their Attributes

The design of our farm information management system comprises of the following components (entities); **Country, City, District, Farmer, Supplier,**

ProductType, Product, Farmland, Planting, Harvest, Pesticide, PesticidePurchase, PesticideStock, PesticideUsage, PesticideType, SoilType, User.

Country (cid, cname, clocation, cicon)

City(ctid, ctcode, ctname, ctlocation, ctcountryid)

District (did, dcode, dname, dlocation, dcityid)

Farmer(fid, fcode, fname, faddress, fcontact, fdistrict, lat, lng)

Supplier(supid, supname, supaddress, contact, cityid, lat, lng)

ProductType(type_id, type_name)

Product(pid, pname, details, ptype)

Farmland(fmid, fmlocation, fmfarmerid, date, soiltype)

Planting(pid, farmid, cropid, plantdate, status, barcode)

Harvest(hid, plantid, harvestdate)

Pesticide(pestid, pestname, pesticidetype, pdetails)

PesticidePurchase(pid, pestid, supplierid, qty, cost, date)

PesticideStock(stockid, pestid, qty)

PesticideUsage(id, farmid, pestid, quantityused, dateused)

PesticideType(type_id, type_name)

SoilType(type_id, type_name)

User(uid, username, password, usertype, email, date)

5.6 Data Dictionary

Table 5.1 Country data dictionary

Name	**Type**	**Description**
cid	int	Stores primary key of a country
cname	varchar(50)	Stores name a country
clocation	geography	Stores geographical location of a country

Table 5.2 City data dictionary

Name	**Type**	**Description**
ctid	int	Stores primary key of a city
ctcode	varchar(10)	Stores code of a city
ctname	varchar(50)	Stores name a city
ctlocation	geography	Stores geographical location of a city
ctcountryid	int	Stores foreign key countryID

Table 5.3 District data dictionary

Name	**Type**	**Description**
did	int	Stores primary key of a district
dcode	varchar(10)	Stores code of a district
dname	varchar(50)	Stores name a district
dlocation	geography	Stores geographical location of a district
dcityid	int	Stores foreign key of a district

Table 5.4 Farmers data dictionary

Name	Type	Description
fid	Int	Stores primary key of a farmer
fcode	Varchar(50)	Stores unique code of a farmer
fname	Varchar(50)	Stores name a farmer
faddress	Varchar(200)	Stores address of a farmer
fcontact	Int	Stores contact of a farmer
fdistrict	Int	Stores district in which a farmer belongs
flocation	geography	Stores geographical location of a farmer

Table 5.5 Farmerland data dictionary

Name	Type	Description
fmid	Int	Stores primary key of a farm land
fmlocation	geography	Stores a geographical location of a farm
fmfarmerid	Varchar(50)	Stores key of a farmer
date	Varchar(200)	Stores date when a farm is recorded

Table 5.6 Pesticidetypes data dictionary

Name	Type	Description
Type_id	int	Stores primary key of a pesticidetype
Type_name	varchar(50)	Stores type name of pesticides

Table 5.7 Pesticide data dictionary

Name	Type	Description
pestid	int	Stores primary key of a pesticide
pestname	varchar(50)	Stores name of a particular pesticide
pesticidetype	int	Stores key of pesticide type
pdetails	varchar(500)	Stores details of a particular pesticide

Table 5.8 Suppliers data dictionary

Name	**Type**	**Description**
supid	int	Stores primary key of a supplier
supname	varchar(50)	Stores name of a supplier
supaddress	varchar(100)	Stores address of a farmer
Contact	varchar(50)	Stores contact of a supplier
Geolocation	geography	Stores geographical location of a supplier
cityid	int	Store district where a supplier belongs

Table 5.9 Pesticidepurchase data dictionary

Name	**Type**	**Description**
pid	int	Stores primary key of a purchase
pestid	int	Stores pesticide key of a purchase
supplierid	int	Stores supplier key of a purchase
qty	int	Stores contact of a supplier
cost	int	Stores geographical location of a supplier
date	date	Store district where a supplier belongs

Table 5.10 Producttype data dictionary

Name	**Type**	**Description**
type_id	int	Stores primary key of a product type
type_name	varchar(20)	Stores name of a product type

Table 5.11 Planting data dictionary

Name	Type	Description
pid	int	Stores primary key of a planting type
farmid	varchar(20)	Stores foreign key farmid
cropid	int	Stores foreign key cropid
plantdate	date	Stores date of planting occurrence
status	char(a)	Stores status of the farm
barcode	varchar(50)	Stores barcode of a product/crop

Table 5.12 Product data dictionary

Name	Type	Description
pid	int	Stores primary key of a product
pname	varchar(50)	Stores name of a product
details	varchar(500)	Stores details of a product
plantdate	date	Stores date of planting occurrence
ptype	int	Stores foreign key of a product type

Table 5.13 Harvest data dictionary

Name	Type	Description
hid	int	Stores primary key of harvesting
plantid	int	Stores foreign key of a product/crop
harvestdate	date	Stores harvest date of a crop

Table 5.14 SoilType data dictionary

Name	Type	Description
type_id	int	Stores primary key of soil type
type_name	varchar(20)	Stores name of soil type

Table 5.15 PesticideUsage data dictionary

Name	**Type**	**Description**
id	int	Stores primary key of pesticide usage
farmid	int	Stores foreign key of a farm
pestid	int	Stores foreign key of a pesticide
quantityused	int	Stores quantity of pesticide used
dateused	date	Stores date when pesticide is used

Table 5.16 Pesticidestock data dictionary

Name	**Type**	**Description**
stockid	int	Stores primary key of pesticide stock
pestid	int	Stores foreign key of a pesticide
qty	int	Stores quantity of pesticide purchased

.

Table 5.17 Users data dictionary

Name	**Type**	**Description**
uid	int	Stores primary key of a user
username	int	Stores username of a user
password	varchar(20)	Stores password of a user
usertype	int	Stores foreign key user type
email	varchar(100)	Stores email of a user
date	date	Store date when a user is created

5.7 Interface Design

The system's interfaces were developed mainly using HTML. The interfaces were designed in a manner that would allow easy interaction and navigation of the system. The index page or home page is the one where authorized users of the system are required to provide the authentication (username and password) to log on to the system and access its resources.

5.8 Architectural Design

Architectural design was considered through identifying the different user modules structures and organization. This identified relationships between major structural elements of the system and the different properties of the elements that comprise the system model.

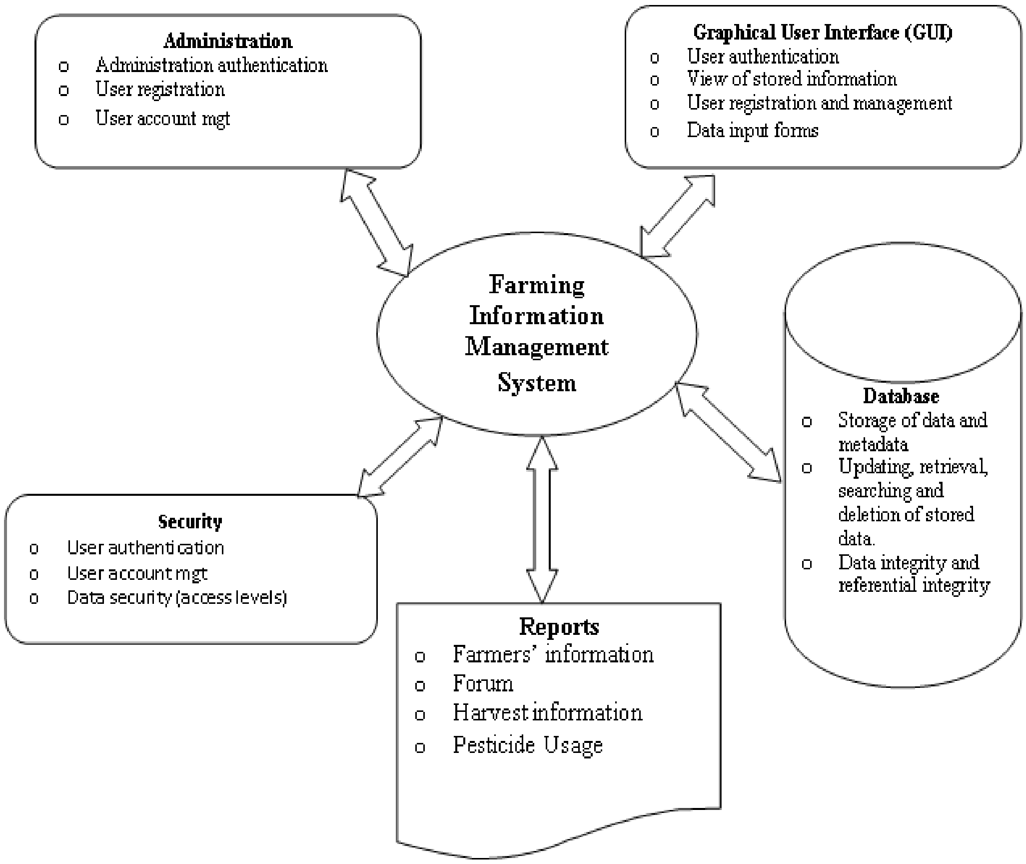


Figure 5.9 Shows the architectural design of the proposed system.

The Figure 5.9 above shows concepts that focuses on the components or elements of a system and unifies them into a coherent and functional whole and gives an overview of how the different components of the system interact with each other.

5.9 System Components

The Figure 5.10 below shows how system components communicate with each other via interfaces. When a component offers services to the rest of the system, the interfaces are linked by php scripts, protocols and web servers which allow them to connect to the MYSQL database.

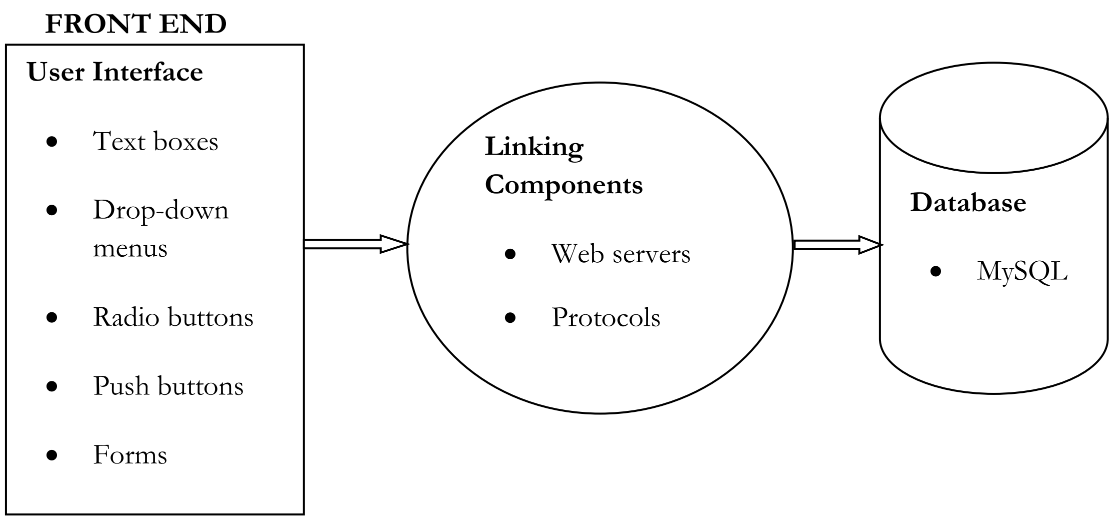


Figure 5.10 Shows system components.

5.10 System Implementation

This section introduces the developed application with emphasis on how it was developed and the program flow. It involves procedures used physically in order to come up with the proposed system.

5.10.1 MySQL

MySQL is the most popular Open Source Relational SQL database management system. MySQL is a fast, easy-to-use RDBMS being used for many small and big businesses. MySQL is developed, marketed, and supported by MySQL AB, which is a Swedish company [MySQL, A. B., & MySQL, A. B. 2008]. MySQL is becoming so popular because of many good reasons:

i. MySQL is released under an open-source license. So you have nothing to pay to use it.
ii. MySQL is a very powerful program in its own right. It handles a large subset of the functionality of the most expensive and powerful database packages.
iii. MySQL uses a standard form of the well-known SQL data language.
iv. MySQL works on many operating systems and with many languages including PHP, PERL, C, C++, JAVA, etc.
v. MySQL works very quickly and works well even with large data sets.
vi. MySQL is very friendly to PHP, the most appreciated language for web development.
vii. MySQL supports large databases, up to 50 million rows or more in a table. The default file size limit for a table is 4GB, but you can increase this (if your operating system can handle it) to a theoretical limit of 8 million terabytes (TB).
viii. MySQL is customizable. The open-source GPL license allows programmers to modify the MySQL software to fit their own specific environments.

5.10.2 MySQL Extensions for Spatial Data

Following the Open Geospatial Consortium (OGC) specification, MySQL implements spatial extensions as a subset of the SQL with Geometry Types environment (Herring, 2011). This term refers to an SQL environment that has been extended with a set of geometry types. A geometry-valued SQL column is implemented as a column that has a geometry type. The specification describes a set of SQL geometry types, as well as functions on those types to create and analyze geometry values. MySQL spatial extensions enable the generation, storage, and analysis of geographic features:

- Data types for representing spatial values

- Functions for manipulating spatial values
- Spatial indexing for improved access times to spatial columns

MySQL was used because of its extensions to support Spatial Database Management System (SDBMS). These are databases that are optimized to store and query data that represents objects defined in a geometric space. It can also be easily integrated with PHP to help build, debug, and operate multi-user applications.

5.10.3 HTML

HTML stands for **H**yper **T**ext **M**arkup **L**anguage. HTML is the basic language which makes the web work and is used by most of the websites. HTML is the most common language which is understood by any computer and the standard compliance for creating simple static web pages. When implemented properly, it is one of the most powerful tools that can guarantee the look of the web pages to be the same in every single browser. HTML files are written in ACSII text, so the user can use any text editor to create his/her web page, though a browser of one sort or another is necessary to view the web page. Delivering host sessions using HTML provides the user with a consistent interface and provides developers with a highly effective medium for presenting information.

5.10.4 PHP

Hypertext Preprocessor (PHP) is a server-side scripting language generally used to create dynamic web pages (Lerdorf, R and Tatroe, K., 1994). PHP can be used as a general purpose scripting language to create command line and desktop GUI applications along with the dynamic web pages. PHP is also very versatile in which it can be installed and configured on nearly any operating system that can build from source code, but also comes prepackaged and pre-installed on many Linux distributions. PHP allows for end users to interact more with the web and create pages with less effort. Without PHP or other like server-side scripting languages, the web as we know it today would be much different.

5.10.5 Google Maps

This is a desktop and mobile web mapping service application and technology provided by Google, offering satellite imagery, street maps and street view perspective, as well as functions such as route planner for traveling by foot, car, bicycle (beta test) or with public transport. This supports maps embedded on third-party website via the Google maps API. These are used to display occurrences of pesticide usage events on the map. After the success of reverse-engineered mashups such as chicagocrime.org and housingmaps.com, Google launched the Google Maps API in June 2005 to allow developers to integrate Google Maps into their websites [Miller 2006]. It is a free service, and currently does not contain ads, but Google states in their terms of use that they reserve the right to display ads in the future.

5.10.6 Apache Web Server

We used Apache as a web server because it serves both static and dynamic content web pages on the World Wide Web. It also enables previewing and testing code during web application development.

5.11 A Model of the Final System

The final system should be in position to perform the following tasks:

i. Perform a quick search of product details. This allows quick and easy retrieval of crop details as well as the pesticides used using barcodes.
ii. System should allow interaction between various users through forum platform.
iii. Should allow the administrator to manage system users such as add and delete users and records to and from the system. This is as a result of the changing needs of the system users.

5.11.1 Interfaces

The Figure 5.11 below shows the login page which system users use to access the system. This is where every user enters his/her credentials namely; **username** and **password**, required to obtain access to a computer system or other restricted area. This helps defend information from unauthorized access, use, disclosure, disruption, modification, perusal, inspection, recording or destruction.

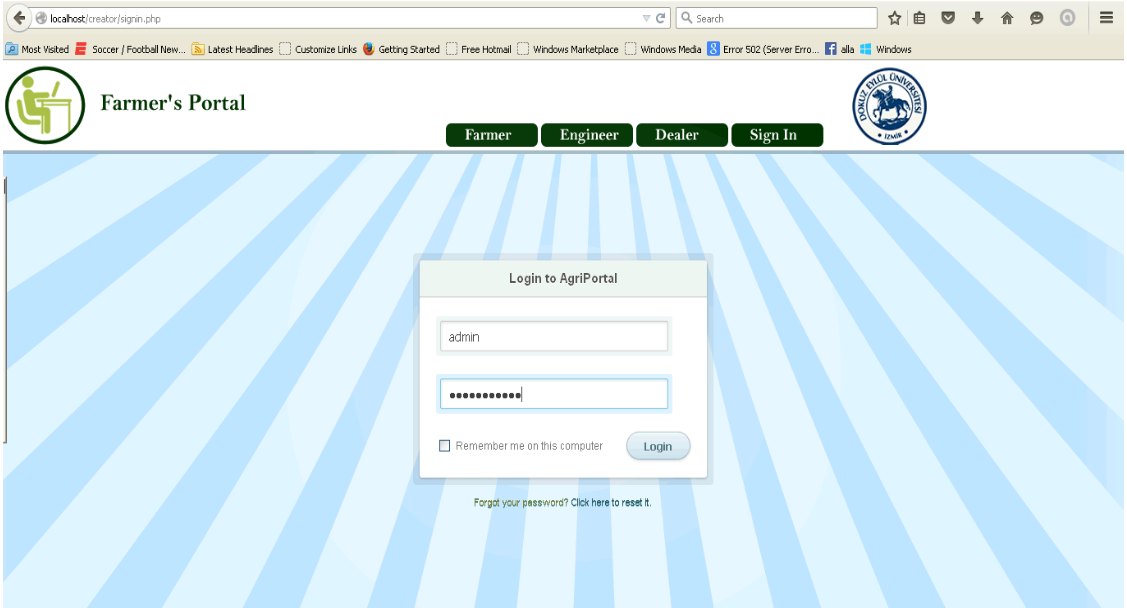


Figure 5.11 Shows a login page for system users and administrators.

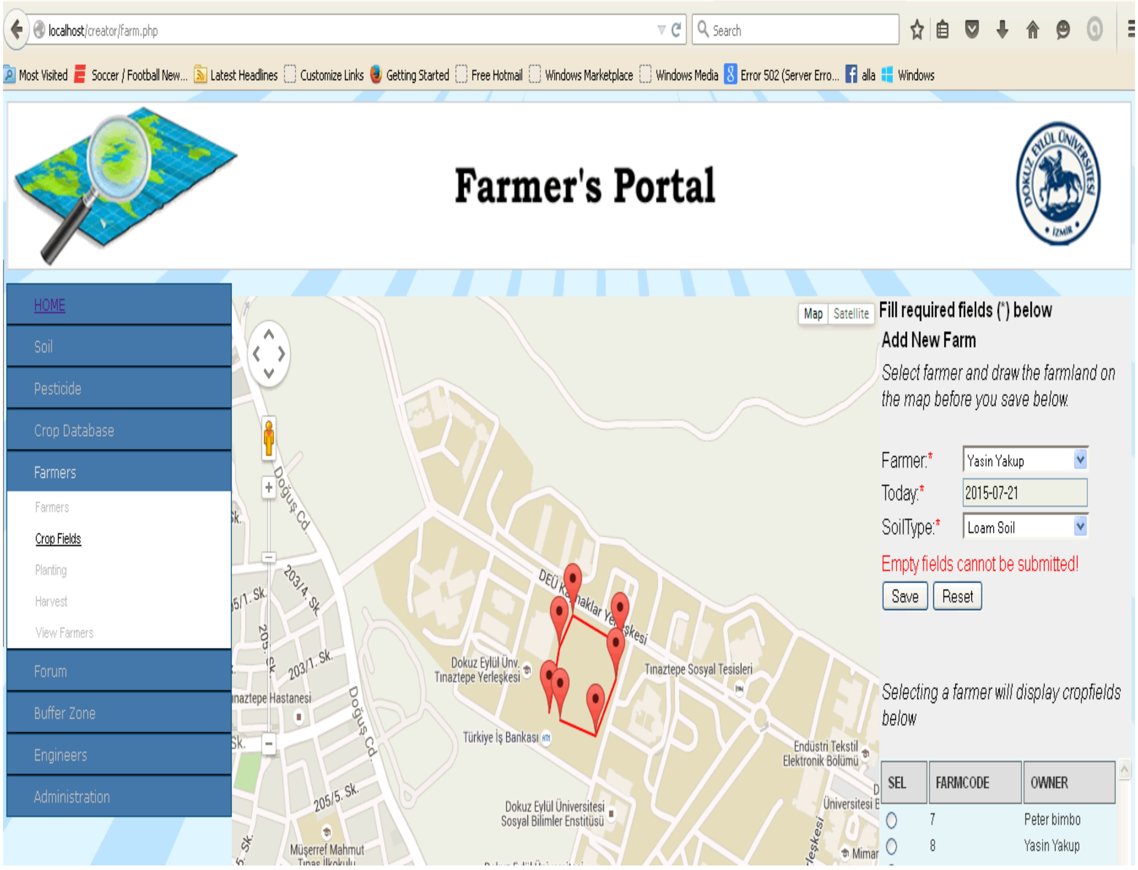


Figure 5.12 Shows a spatial data capturing page for farmers.

This page in Figure 5.12 enables farmers to capture and save all the data and information regarding crop fields which can be later be viewed on Google maps as depicted in Figure 5.13 below. By doing this, both spatial and non-spatial data is/are generated which in turn we use for spatial analysis and other knowledge discovery purposes.

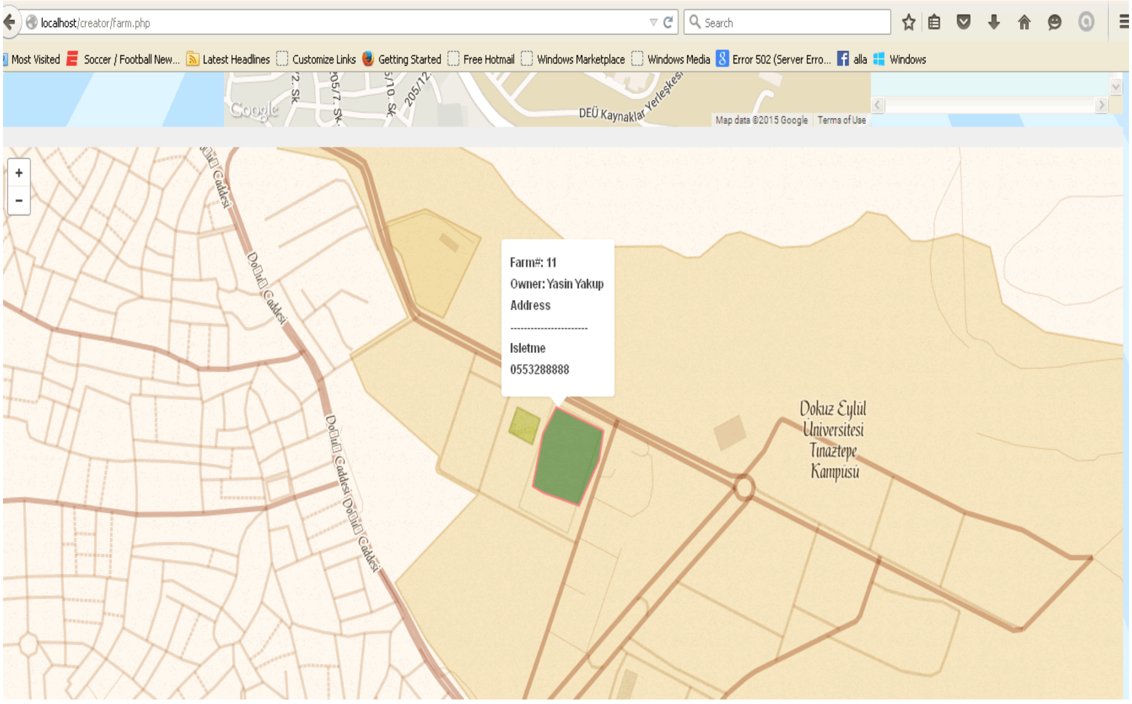


Figure 5.13 Shows the physical location a crop field or farm on Google map.

The page in Figure 5.13 above depicts a farm or crop field on a map. Google maps enable us to create a visually rich experience that engages your users, encouraging a higher level of interaction. Whenever you have data that has a geographic reference such as an address or lat/long coordinates, it's an opportunity to provide a more engaging experience through a map.

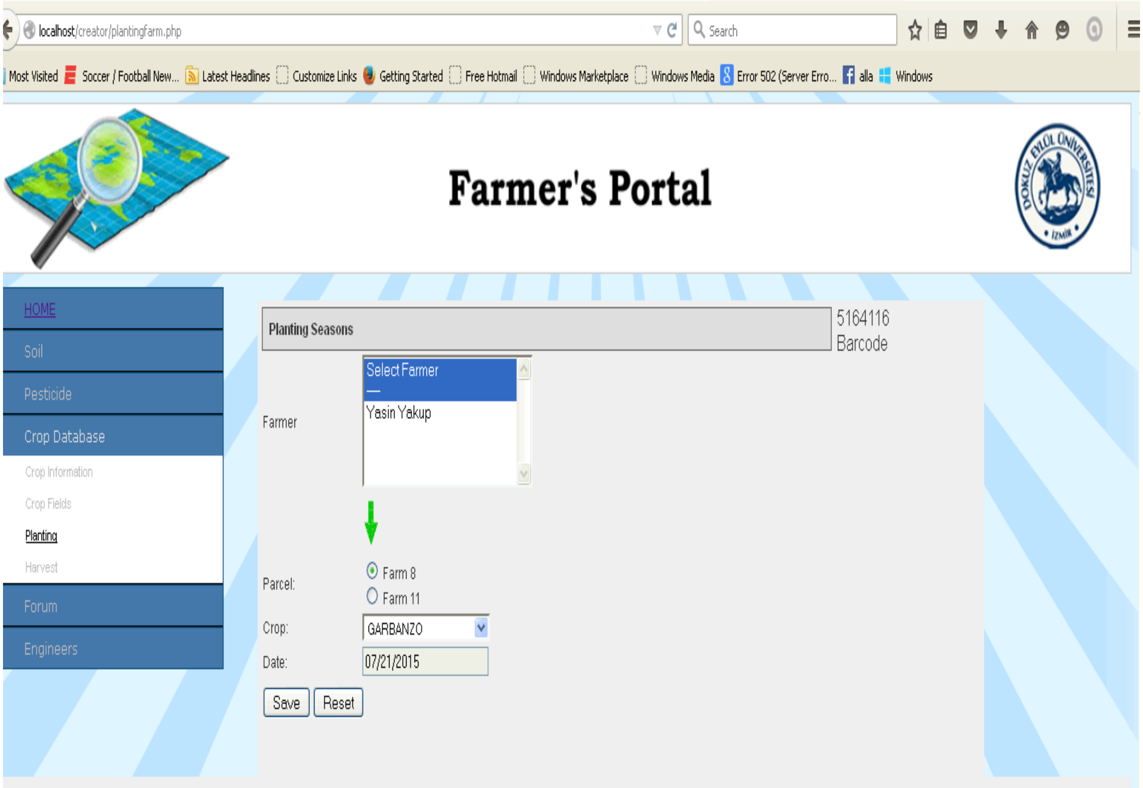


Figure 5.14 Shows farmer's page that is used to capture data regarding planting season.

The page in Figure 5.14 above shows a web page farmers use to record information about planting season. This records the farm, the type of crop grown on that farm and the date when planting takes place. In addition, a barcode is assigned to that particular crop which can be used by other stakeholders such as dealer to search and learn more information about the crop.

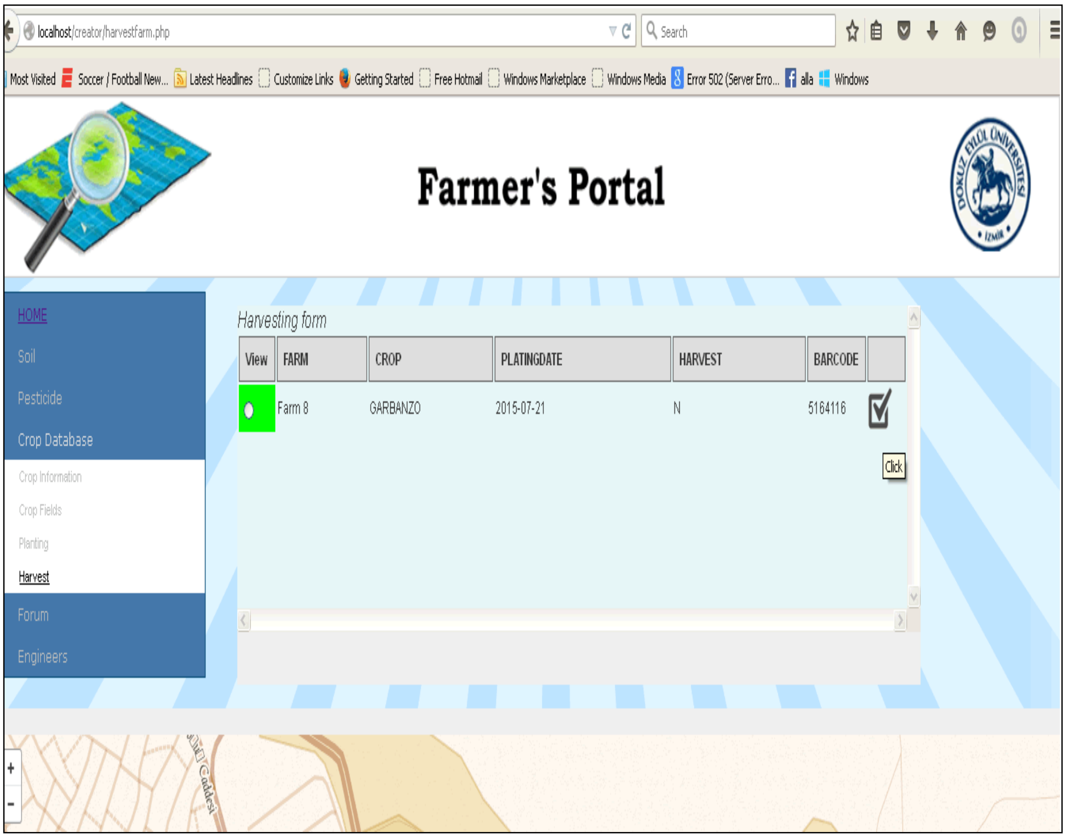


Figure 5.15 Shows harvest page that is used to record data regarding crop harvest.

The web page in Figure 5.15 above is used to activate harvest process on farms. By checking into the system, dealers are able to know harvests that have taken place, thus allowing them to plan their next moves.

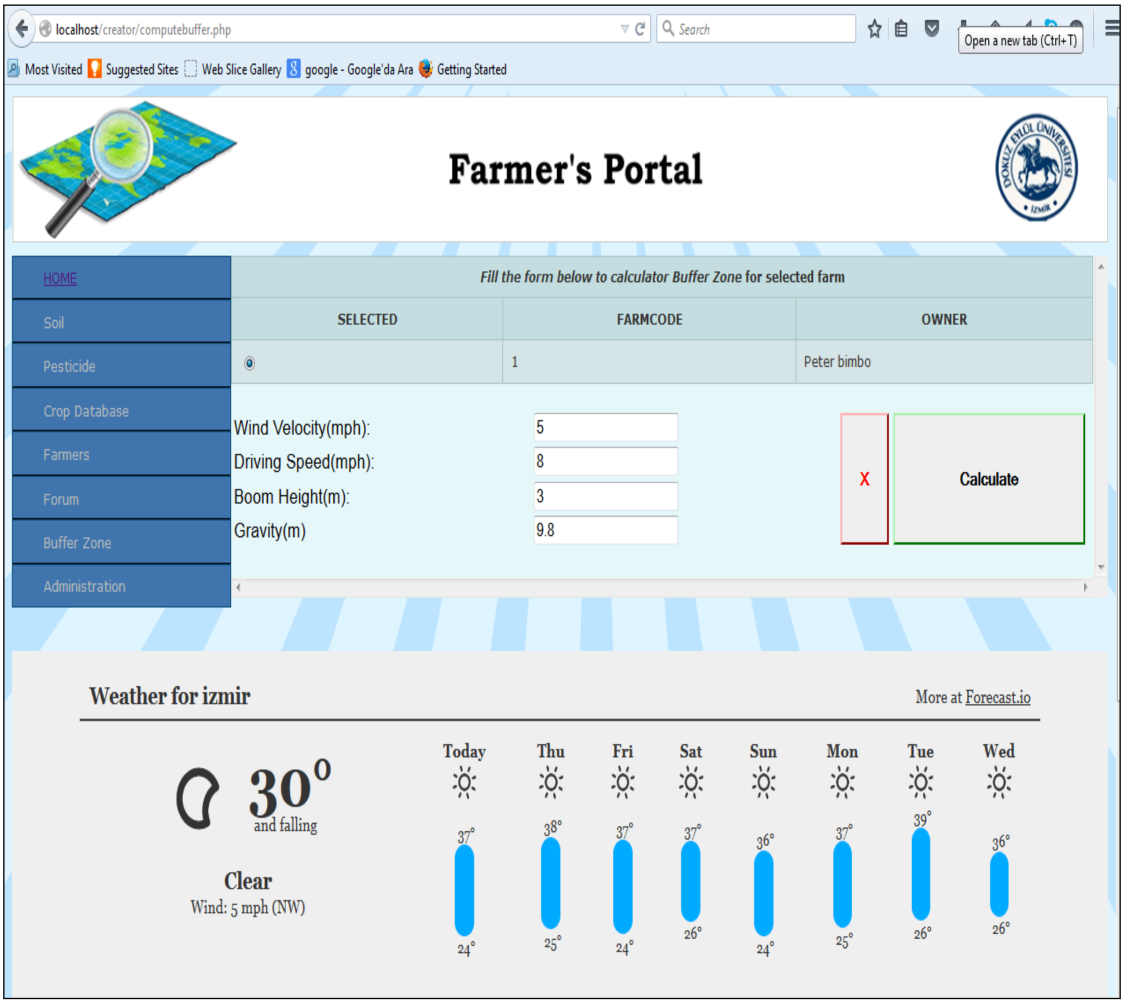


Figure 5.16 Shows a web form that is used by farmers to calculate spray drift distance.

The page in Figure 5.16 depicts spray drift distance calculation. This includes, wind velocity, driving speed both measured in mile per hour, boom height which is measured in meters and gravity that is measured in meters per second squared. After distance is obtained, it is this distance that is appended on every point of the polygon (crop field) to allow create a reserve/buffer zone where no pesticide should be applied.

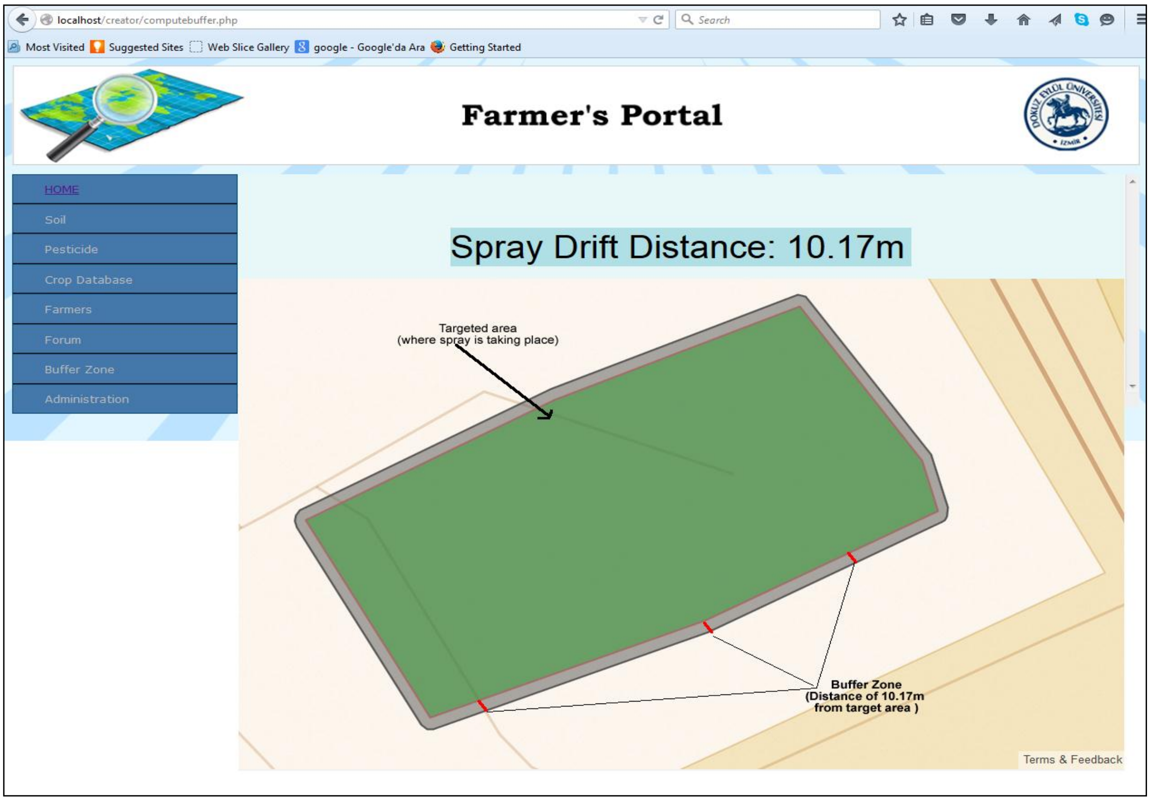


Figure 5.17 The buffer zone that should be observed when applying pesticides.

Drift distance data obtained varies interms of wind velocities (mph), boom height (m), and gravity (m / s^2) can be seen in Table 4.2. This was used to simulate various drift distances on google maps. From this table, relative drift distances for water droplets with initial wind speed (5, 6, 8, 10, 16, 19 mph), driving speed (8, 7, 6, 5, 4, 3 mph), boom height (3 m) and constant gravity (9.8 m / s2) can be observed. For instance, spray application carried out at wind speed of 5mph, driving speed of 8mph, boom height of 3m and with gravitational forces of 9.8 m / s^2 was able to travel 10.17m.

CHAPTER SIX
CONCLUSION AND FUTURE WORK

6.1 Conclusion

In this thesis, we propose an agricultural information system for farmers to optimize pesticide usage by spatial-temporal databases. These databases need to accommodate both spatial and temporal attributes such as space and time. Extended UML was used in this case study to reveal several possibilities on how spatial properties can be modeled. The spatial-temporal characteristics are key for geographic data and also show how different ideas that exist when modeling these properties. Further more, extended UML provides small set of new concepts for spatial-temporal data which minimizes the complexity of the resulting designs (schemas). This gives the application developers an opportunity to concentrate on the properties of a specific application domain of interest. Extended UML was applied in real application for the development of an agricultural information system that helps optimize pesticide usage on crop fields. With smaller prototypes, encouraging results were observed: diagrams were well understood by the developers and data modeling processes went on more fast.In addition, extended UML revealed topological relationships between spatial objects that can be explicitly represented in the schema diagram using spatial relationships.

The study shows further more that through GIS, a successful implementation, scientific monitoring and layout, guiding of scientific decision making and timely information can be provided to help farmers achieve higher production. This improves the level of quality and added-value of agricultural productions and in turn save resources. When spatial data are available at the farm or section level, GIS can be used to generate spatially explicit maps showing the locations of the nontarget crop fields at potential risks from spray drift depositions. It will also help overcome market problems and decrease destruction of ecological enviroment caused by pesticide drifting. Demonstrations can show that potential crop land areas at risk of unintended pesticide exposure from the near field spray drift can be estimated with reasonale accuracy and precision.

6.2 Future Work

By investigating deeper, the results of this research also provide a strong foundation for future work. One area of future work is in combining the knowledge gained about geographic data with the knowledge about Data Mining. The research also anticipates to extend this project to a large number of stakeholders namely; farmers, dealers, agricultural engineers, agrochemical companies and consumers. We also plan to continue to the next phase of our project to make it accessible through smart phone that most farmers own and know how to use effectively. This would enable farmers gain modern farming techniques which will considerably increase production. This also would help farmers easily sell their products after harvest. To dealers, they would find it easy to search and locate products of their choice depending on the demand in the market. This will also enable agricultural engineers to easily deliver or conduct consultancy business to farmers. Furthermore, agrochemical companies would want to sell their products such as fertilizers and pesticides to farmers which can be made easily with the use of this system. Finally, consumers who are the end and most crucial stakeholders in this would want to observe and know the amount of pesticides used on particular crops before they can consume them.

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APPENDICES

Appendix A

This is an example of basic server and database connection in PHP.

```php
<?php
# FileName="Connection_php_mysql.htm"
# Type="MYSQL"
# HTTP="true"

$hostname_connection = "localhost";
$database_connection = "polygons";
$username_connection = "root";
$password_connection = "dubai";
$connection = mysql_pconnect($hostname_connection, $username_connection, $password_connection) or trigger_error(mysql_error(),E_USER_ERROR);
mysql_select_db($database_connection,$connection);


?>
```

Appendix B

This is an example of buffer zone calculation.

```
    //pts
    layer.options.draggable = true;
    layer.on('drag', function(e) {
        calculateBuffer();
    });
    //lines and polys
    if(layer.editing){
        layer.editing.enable();
        layer.on('edit', function(e) {
            calculateBuffer();
        });
    }
});

fcLayer.addTo(map);
calculateBuffer();
//---------------------------------------------------------------------------------
function calculateBuffer() {
    var fc = turf.featurecollection(fcLayer.getLayers().map(function(f){
            return f.toGeoJSON()
        }));
    var buffer = turf.buffer(fc, <?php echo $bz; ?>, 'feet');
    buffer.properties = {
        "fill": "#FF00BF",
        "fill-opacity": 0.5,
        "stroke": "#AC58FA",
        "stroke-width": 3,
        "stroke-opacity": 1,
        "title": "Sports Pitch"
    };
    bufferLayer.setGeoJSON(buffer);
}
//---------------------------------------------------------------------------------
</script>
```