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WEB GIS TO SUPPORT IRRIGATION MANAGEMENT

A Prototype for SAGRA Network, Alentejo Portugal

Ashwin Dhakal

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A Prototype for SAGRA Network, Alentejo Portugal

Dissertation supervised by

Professor Miguel Neto, Ph.D

Dissertation co-supervised by

Professor Mario Caetano, Ph.D

Professor Filberto Pla, Ph.D

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ABSTRACT

An efficient water management, not only allows significant savings in costs of irrigation, but also an effective control on the quality of products, which can have obvious consequences on income operation and reducing the environmental impact of irrigation.
As the Internet is becoming the easiest way of information distribution, irrigation management system can also be benefitted with it. Integrating GIS functionality with internet capacity will redefine the way of decision making, sharing and processing of information. In irrigation systems weather plays an imperative role in decision making, implementing and forecasting. Temperature, humidity, precipitation, and solar radiation are the most important parameters to calculate evapotranspiration by which crop water requirement can be determined.

SAGRA (Sistema Agrometeorológico para a Gestão da Rega no Alentejo) network is providing information to the farmers through web but still lacks the use of GIS in their information to decision support system. Irrigation management support system can be benefitted with the use of Web GIS. In this thesis, web based GIS is designed using popular open source tools and software. Using data from automatic weather station maps are produced using Geo-statistical interpolation techniques and published in web map. These maps can be viewed with popular online maps like Google maps, Microsoft Bing and Openstreet maps.

Animated weather maps are also created which are useful for visualizing changing pattern of weather parameters and water requirement over time.

KEYWORDS

Geovisualization

Map animation

Open source

Web GIS

Weather map

Weather stations

ACRONYMS

API - Application Programming Interface

CAOP - Carta Administrativa Oficial de Portugal

COTR- Centro Operativo e de Tecnologia de Regadio

DOM- Document Object Model

ET- Evapotranspiration

EPSG - European Petroleum Survey Group

EU - European Union

FAO- Food and Agriculture Organization

GIS - Geographic Information System

OGC - Open Geospatial Consortium, Inc.

PGI - Protected Geographical Indication

SRS ID - Spatial Reference System Identifier

SAGRA -Sistema Agrometeorológico para a Gestão da Rega no Alentejo

TMS- Tiled Map Service

TSG - Traditional Speciality Guaranteed

WCS - Web Coverage Service

WFS - Web Feature Service

WKT - Well-known text

WMS - Web Map Service

WWW – World Wide Web

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1. Introduction

Proper irrigation scheduling, based on timely measurements of soil moisture content and crop water needs, is one of the most important management practices for irrigation management (Waskom, 1994). Irrigation water requirements optimization requires proper irrigation scheduling based on the crop water requirements of the different crops (Garg et al, 2003). The balance between input and output in agriculture farm is essential for its success and profitability. Using agro-meteorological weather station data to determine crop water needs provides relevant information to schedule and decide the irrigation for optimization of cropping pattern based on crop, soil and climatic characteristics to ensure maximum return**.**

The ability of GIS to analyze and visualize spatial and non spatial data in the form of maps made it an essential tool for agricultural irrigation management systems. GIS is currently converging with several other technologies to provide new levels of accessibility and functionality (Drummond et al, 2008). As web technologies and the GIS advanced considerably and practiced widely (Tan, 2003) the web based GIS has become a popular means of information sharing and visualization.

COTR is providing technical support and assistance to the farmers for the better implementation of technology. SAGRA network is providing weather information to the users through web in the form of tables and graphs. It is challenging to represent entire region with limited no of weather station information. The incorporation of Geographic information system can be very useful to provide information in the form of maps and publish in the web.

With Web based GIS and animated maps will present weather parameters to the users and decision makers in the form of interpolated maps interactively. In this prototype the data from fourteen weather stations is used to make web maps of the region using open source software. It also includes visualize maps visualization by animation and provides platform to store and retrieve existing maps.

1.1 Problem statement

Operational and Technological Irrigation Centre (COTR) is operating SAGRA network to provide weather information and calculated evapotranspiration through the web. All the information they have been producing to support irrigation management to farmers is made available through the web (desktop and PDA) in the form of tables and graphs (Maia, Neto et al, 2007). The variability in spatial and temporal components is difficult to transmit with traditional analytic techniques since the information is provided in simple graphs and tables. The systems only provide information of point locations where weather stations are located. Weather stations only provide the value of weather parameters for a specific weather point. Geographic information Systems can be a very useful tool to provide information to the farmers in the form of maps using interpolation. These maps can be easily understood by farmers, planners and specialists for irrigating, planning and research. Maps can provide information most effectively but currently there is no such mechanism to provide web maps about crop water needs and weather maps.

1.2 Objectives

1. Create different interpolated maps based on information provided by SAGRA weather station using Geo statistical tools.
2. To develop a web GIS for the study area to visualize and analyze the crop water requirement maps using data from weather the stations using open source software and tools.
3. Animate weather and evapotranspiration map using Geovisualization techniques, to support analysis and decision making process.

4. Display developed maps with Google maps, Bing Map, Google Earth and other online mapping services also prepare animated maps to visualize change pattern.
5. Explore the different mapping technology to solve the problem.
6. Develop a system to store and display stored maps.

1.3 Thesis structure

There are six chapters in the thesis.

Chapter one introduces the thesis in general, and describes problem statement and explains the study area.

Chapter two deals with theoretical background about irrigation water requirement especially evapotranspiration. This chapter also describes theoretical background of web mapping technologies, open standard specification, open standard software, components of mapping technology and concept of geo-visualization.

In *chapter three*, provides general description of software used in this thesis work. This chapter also describes features of software and implementation strategy of the software.

Chapter four describes the materials used in the work, data sources, and requirement analysis of the prototype. This also describes methodology used in the implementation of the prototype, including web map design, animation and storing map in server.

Chapter five provides the implementation results and shows the interfaces of web and animation.

Chapter Six describes limitations and further development of the system.

Finally the conclusion of the thesis is described in the last chapter.

1.4 Study Area Description

The study area, Alentejo region, is situated south of Portugal between Tejo River and Algarve Region in the south of Portugal. The area is bounded with Spain in the east, with Atlantic Ocean in the west and Algarve region in the south. The area was considered as bread basket of Portugal due to its extensive farming and cereal production. The economic indicators are below the Portugal averages and population density is low. Agriculture is important to the regional economy and employment but available water resources are scarce and the rainfall has a significant spatial and temporal variability (Fragoso and Lucas, 2009).This region is famous for its wheat fields, cork and olive plantation. Other major crops produced in this region are maize, potatoes, rice vine tomatoes, sunflower, and melon (Sen, 2004).

The study area was selected where The Irrigation Technology Center (COTR) is working in irrigation management. The potential area consists of about 150000 hectors of irrigated land (Maia, Neto et al, 2007).

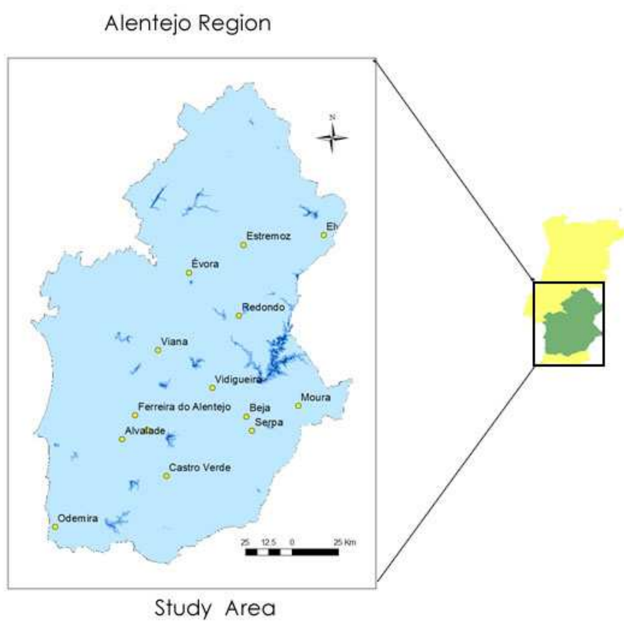

Figure 1 Study Area (Alentejo, Portugal)

The climate is Mediterranean semi-arid and dry with oceanic influences, showing big variation between summer and winter (Frances', 2008). During June and September temperature is warm and dry whereas during October and March 75% rainfall occurs. Rainfall regime is highly irregular, with some torrential events (Cortez, 2004). The significant amount of rainfall in the winter and spring there is excess of water for winter crops (Sen, 2004)

1.5 SAGRA Network

The SAGRA (Sistema Agrometeorológico para a Gestão da Rega no Alentejo) project is conducted by COTR since 2001 which currently consists of 14 automatic agro metrological stations and a hub located in Beja south of Portugal. The table 1 and Fig. 4 show the station number, location and name of the stations. By using these weather data reference evapotranspiration (ETo) is determined (COTR, 2009).

Station No	Latitude	Longitude	Name
1001	-8.2664	38.045	Ferreira do Alentejo
1002	-7.2675	38.0875	Moura
1003	-7.0989	38.9156	Elvas
1004	-7.6278	38.5281	Redondo
1005	-8.1903	37.9714	Aljustrel
1006	-8.3458	37.9289	Alvalade
1007	-7.585	38.0375	Beja
1008	-7.9361	38.7378	Évora
1009	-8.7533	37.5017	Odemira
1011	-8.1256	38.3608	Viana
1012	-7.5969	38.8722	Estremoz
1013	-8.0765	37.75	Castro Verde
1014	-7.7931	38.1769	Vidigueira
1102	-7.5508	37.9683	Serpa

Table 1 Weather station number, location and Name

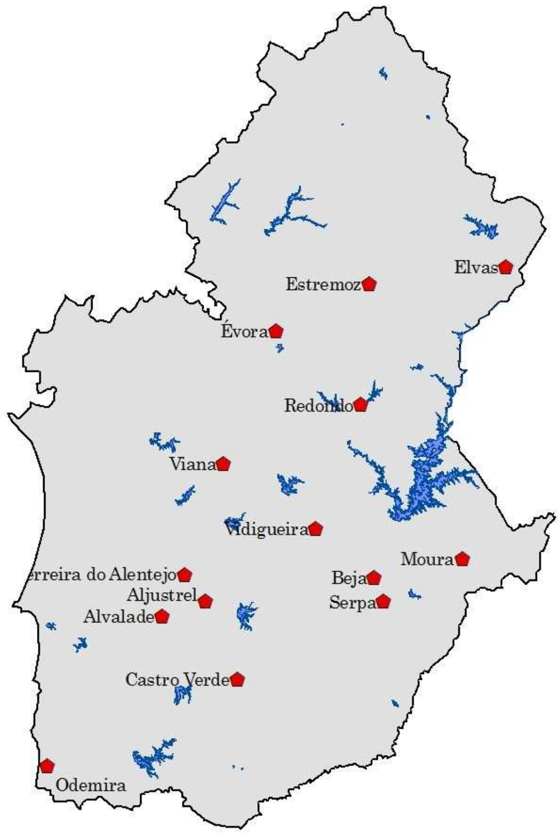

Figure 2 Weather stations and locations

The COTR is involved in irrigation management and responsible for making the available tools through the Web irrigation management using the information network of SAGRA, according to the databases of soils and crops that the COTR has developed and managed. In addition to this activity it has been providing the SMS service, to disseminate information through the network of users, in order to obtain a wider scope, taking advantage of the wide diffusion of mobile(COTR,2010).

The main objectives of SAGRA network are

- Provide users more real data to enable them to produce more efficiently with less water consumption.
- Use of water for agriculture by reducing effort for more efficient irrigation
- Reduce the consumption of energy used in pumping irrigation

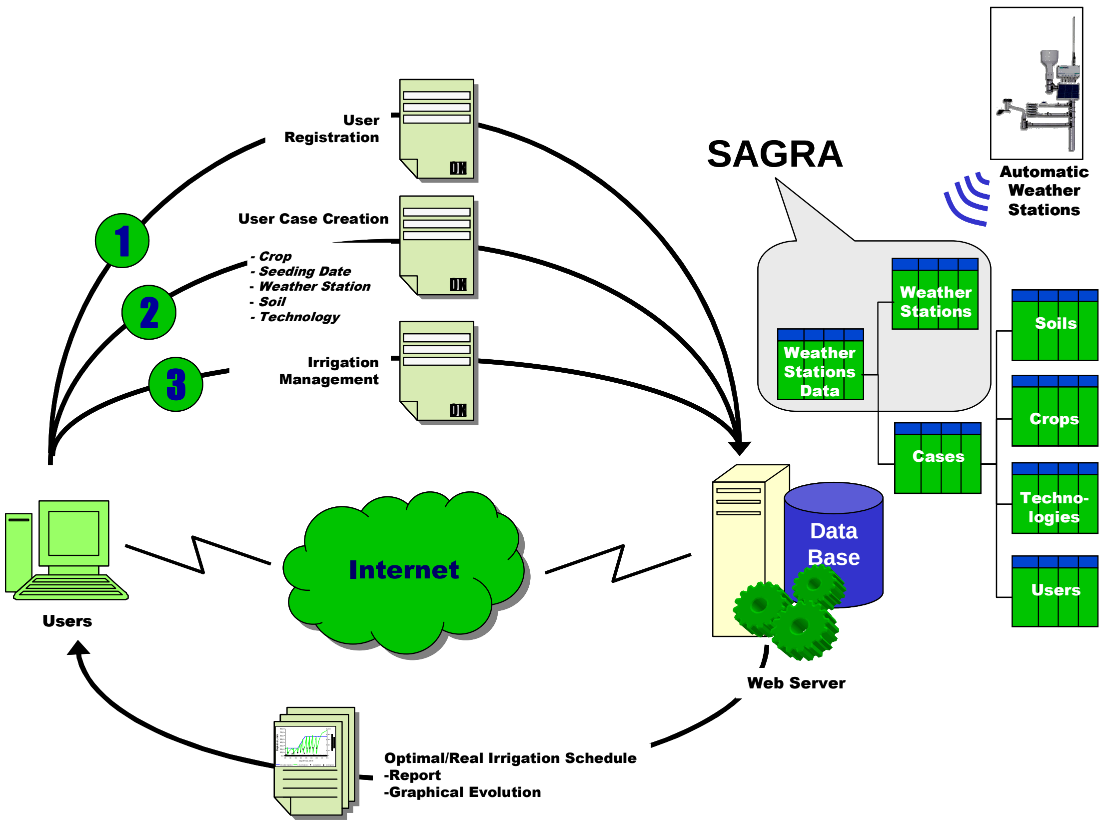

Figure 3 Decision Support System scheme(Maia et al ,2005)

Fig 4 shows the overall decision system of SAGRA network.

According to activities plan 2010 other activities conducted by SAGRA are

1) Prepare agro meteorological information and support to the farmer's decision on the various services, including: irrigation management, crop protection, etc;

2) Ensure the quality of information available through the maintenance of Meteorological Network.

3) Determine the evaporation of the main crops of the areas of influence of climate zones and validate the crop coefficients of the main crops;

4) Implement programs and manage on the WEB allowing the development of irrigation schedules.

5) Cooperate in providing support services to the irrigation management to individual farmers Private, covering various cultures (vineyards, olive and tomato), with elaboration of management reports customized watering weekly during the irrigation.

6) Calibrating ETo estimated by the Hargreaves method for plants

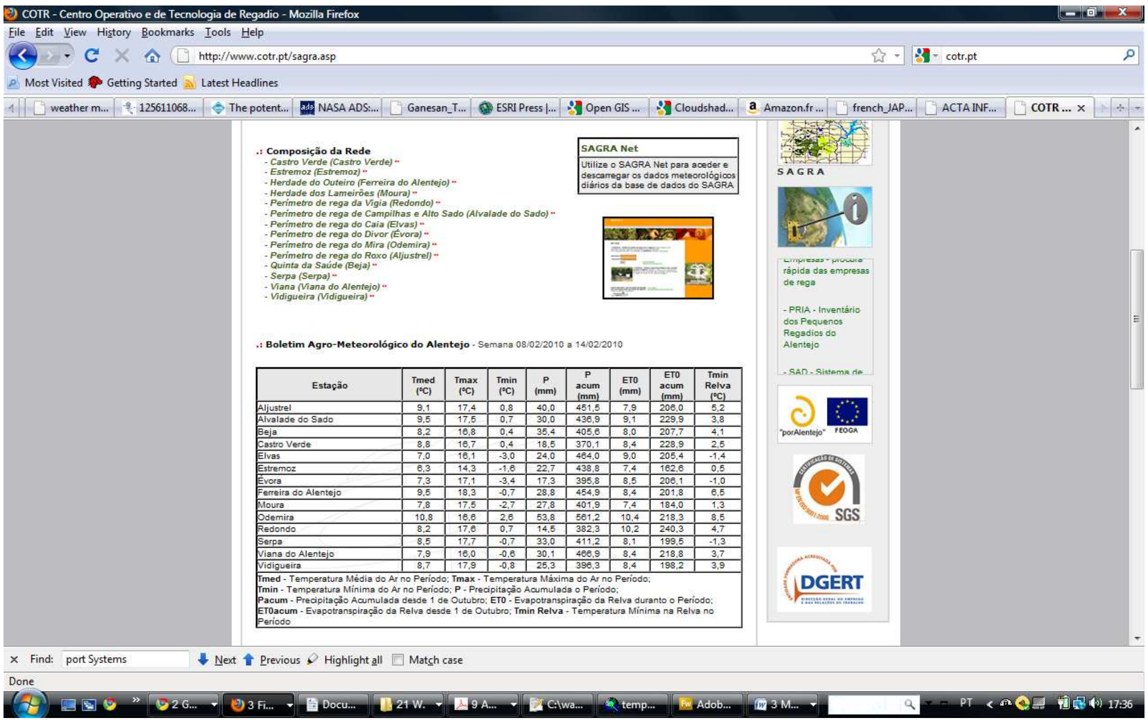

Figure 4. Interface of SAGRA web page

As mentioned earlier, SAGRA network currently consists of 14 weather stations that collect weather information for calculating crop water needs. This information is used to provide agro meteorological information and support the farmer's decision on their irrigation and crop scheduling. Fig 5 shows interface of the website.

2. Theoretical Framework

2.1 Irrigation management

An efficient water management, not only allows significant savings in costs of irrigation, but also an effective control on the quality of products, which can have obvious consequences on income operation and reducing the environmental impact of irrigation.

The irrigation management for agricultural production in water scarcity regions requires innovative and sustainable research, and an appropriate transfer of technologies **(**Pereira et al, 2002)**.** Irrigation management is a key to efficient and timely water distribution in canal command areas keeping in view the crop factors, and for irrigation management adequate and always updated information regarding the irrigation system is needed (Pervej, 2004). Crop water requirement is determined by calculating evapotranspiration of the crop using method recommended by FAO.

With the development of the irrigation technologies, the irrigation management methodology also changes accordingly. An efficient water management, not only saves significant cost, time and resource on irrigation but also provide effective quality control of the product reducing significant savings in cost. Irrigation management is considered core activity to reduce the amount of water consumption in agriculture.

One example of the attempts to build weather maps for agriculture was implemented by Northern Colorado Water Conservancy District (NCWCD) in Colorado, USA. The district is a public agency and provides water for agriculture, domestic and industrial uses in north-eastern Colorado. Twenty three automated weather station sites provide weather parameters to calculate evapotranspiration for crops. The ET data is used to conserve water used for irrigation. Every day the weather maps of previous day are updated. The maps for temperature, precipitation, radiation and humidity are displayed in static and less interactive way.

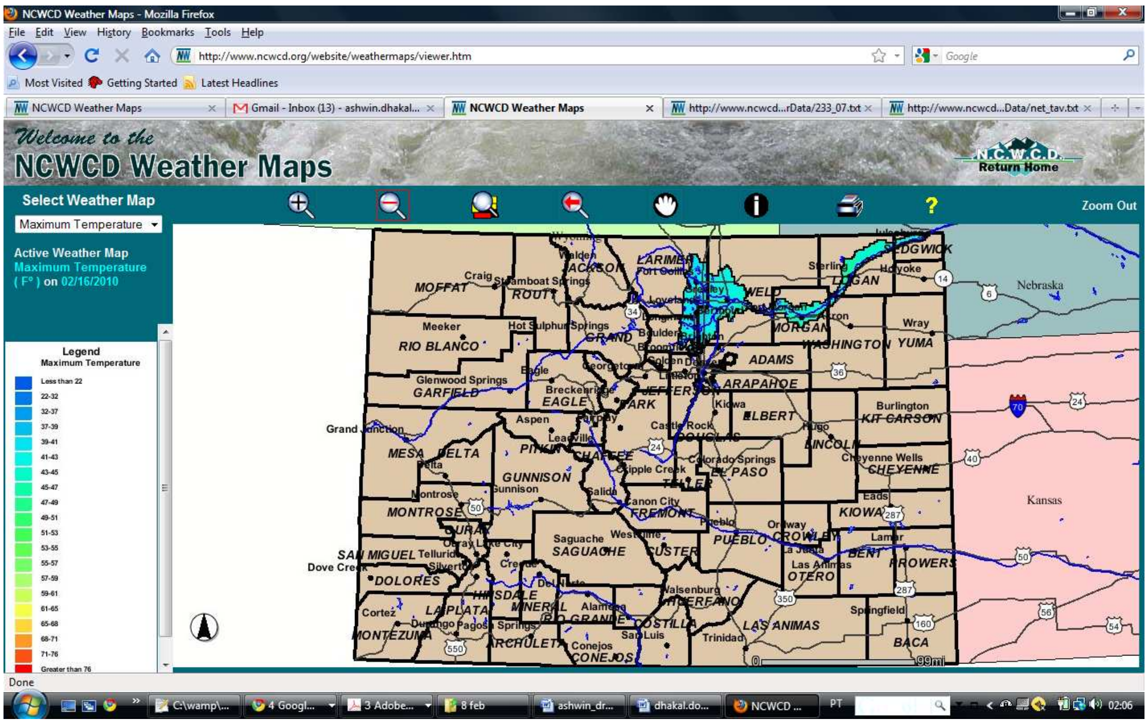

Figure 5 Weather map for North-eastern Colorado, NCWCD

Similarly, California irrigation management information system (CIMIS) which is conducted by California Department of water resources consists of 130 automatic weather stations and these weather stations provide weather data on daily basis. Using these data ETo and solar radiation maps are produced and published in their web page http://www.cimis.water.ca.gov/cimis/cimiSatOverview.jsp.

2.1.1 Evapotranspiration

From the literature, Estimation of the water requirement is a key part of design and operation of agricultural water resource systems (Yoo et al, 2008). The ET information must be adjusted to correspond to the crop and climate. ET is a combination of the water evaporated from the soil surface and transpired through the plant (MAOFF BC, 2001).

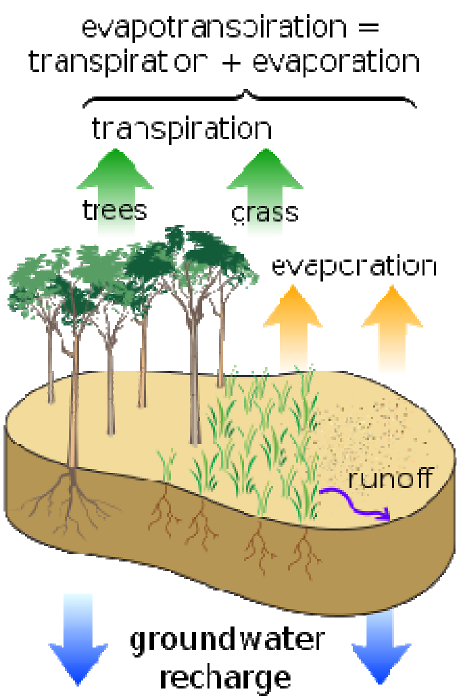

Figure 6 Conceptual diagram evapotranspiration, runoff, and recharge process[1].

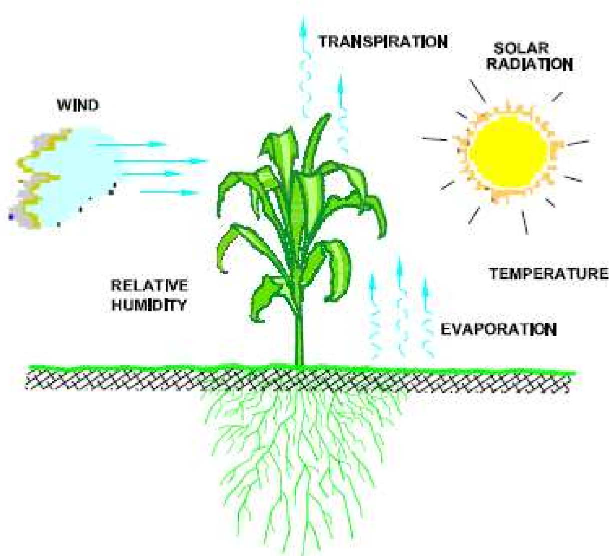

Figure 7 Elements for Evapotranspiration (MOAFF, BC)

[1] http://en.wikipedia.org/wiki/File:Surface_water_cycle.svg

2.2.2 Reference crop evapotranspiration (ETo)

According to FAO Irrigation and Drainage paper-56, the evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ETo. The reference surface is a hypothetical grass reference crop with specific characteristics.

2. 2.3 Crop Water Use

The estimation of consumptive use for irrigated crops is determined by the crop coefficient-reference evapotranspiration procedure (yoo et al, 2008). Reference evapotranspiration (ETo) is computed for a hypothetical reference crop according to the FAO paper no. 56 methodology (Allen et al., 1998) and is then multiplied by an empirical crop coefficient (Kc) to produce an estimate of crop evapotranspiration (ETc). Crop water use is directly related to ET. The crop's water use can be determined by multiplying the reference ETo by a crop coefficient (Kc). The crop coefficient adjusts the calculated reference ETo to obtain the crop evapotranspiration Etc (yoo and et al, 2008). Different crops will have a different crop coefficient and resulting water use. (MOAFF, 2001)

ETc = ETo x Kc

Where ETo = calculated reference ET for grass (mm)

Kc = crop coefficient

ETc = crop evapotranspiration or crop water use (mm)

2.2.4 FAO Penman-Monteith Equation

A series of researches were conducted by the FAO in 1990 to review the FAO methodologies on crop water requirements to advice on the revision and update of procedures (Allen and et.al, 1998). The equation for ETo recommended by FAO-PM is:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

Where,
ETo- reference evapotranspiration [mm day-1],

Rn -net radiation at the crop surface [MJ m-2 day-1],

G -soil heat flux density [MJ m-2 day-1],

ea- actual vapour pressure [kPa],

T -mean daily air temperature at 2 m height [°C],

U2- wind speed at 2 m height [m s-1],

es- Saturation vapours pressure [kPa],

es - ea saturation vapour pressure deficit [kPa],

Δ-slope vapour pressure curve [kPa °C-1],

y-psychrometric constant [kPa °C-1].

2.3 GIS and web Mapping

GIS has capabilities to integrate database, statistics, remote sensing, maps with advance graphics for visualization and analysis. Spatial database such as soil, rainfall, geology, land use, transportation, topography, demography and socioeconomic can be implemented for better decisions in resource or facilities planning and management. With its powerful capacity for management and analysis of spatial data, GIS becomes an important tool in irrigation management (Lin et al, 2004).

2.3.1 Web Mapping

Web GIS is the process of designing, implementing, generating and delivering maps on the World Wide Web (Wikipedia, 2010). Web mapping looks similar with web GIS but web GIS deals with processing of geo-data bases, analysis, exploratory issues (Kraak, 2004). The web mapping basically deals with technical issues, web based cartography theory issues social issues and usability of maps. It is the presentation media for web maps and gaining more analytical capabilities.

GIS integrates and relates data with spatial component and supports users to view in proper format which supports in making complex spatial decisions through visualization, interactive modelling and analysis environments. GIS is thus far utilized to help with perception and understanding of spatially distributed phenomena in many areas of decision making and evaluating problems (Sakamoto and Fukui 2004). Generally GIS systems were considered as monolithic and platform-dependent applications (Wong et al., 2002). The development and rapid growth of web and web based application created a new platform for traditional GIS to grow and spread. Unfortunately, not everyone has access to GIS, nor would be able to spend time necessary to use it effectively. Web GIS became a cheap and easy way of disseminating geospatial data and processing tools (Alesheikh et al, 2002). Web GIS have the highest number of users, although typically Internet users focus on simple display and query tasks. (Goodchild et al, 2005). The capability of Web GIS for interacting dynamically in distributed environment from cross platform to client/ server computing system made it more interesting to develop and use for accessing spatial information.

The major development of cartography is using web as a distribution medium. By the means of web, now it has opened the possibility of the availability of real-time maps, cheaper maps sharing, more frequently updated database sources and cheaper software and hardware requirement. There are some problem and difficulties for fully development of web mapping. Some technical difficulties such as bandwidth, lower resolution of image are common. Reliability issues and security issues are limited the expansion of web mapping.

The development of web cartography and GIS is steady as compare to web technologies. Web 2.0, a new generation of Internet services and technology (Deshpande et al, 2006), support user interaction significantly. This evolution leads GIS away from data browsing, analyzing and managing for individual decisions, and more towards group participating and communicating on social decision issues (Carver 1999). As Craig et al. (1999) describe the Public Participation GIS principles as accessibility, understand ability, and accountability, Web GIS continues to draw attention as a public participation tool (Sakamoto et al 2004).

Nowadays, Google Maps, Google Earth, OpenStreet Map, Yahoo Maps, Microsoft's Live Search Maps and other many commercial as well as non-commercial applications provide many kinds of geographical related information such as detailed maps, satellite images and terrain maps covering all over the world and allow users to use their APIs.(Zhelu, 2009).

2.3.2 Advantages of web mapping

Web mapping improves communication with the users who understand maps and it the easiest way to improve the internal and external communication (Stachowicz , 2004). In distributed and heterogeneous network environments web GIS provides interoperability, reusability, and flexibility (Tsou et al, 2002). The clients or users are free to use the stored large amount of data. It reduces the major problem of database collection and searching.

2.4 Components of Web Mapping

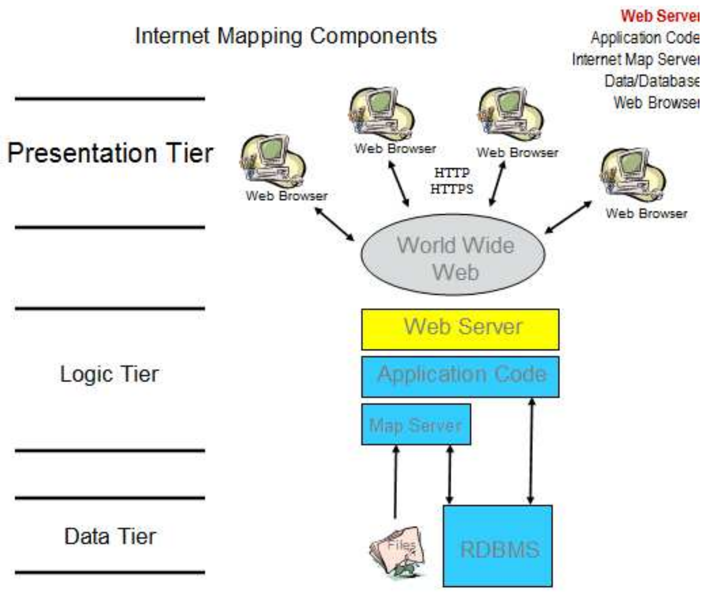

Figure 8 Components of Web Mapping,(Crocker Farallon Geographics.)

2.4.1Presentation tier:

The presentation tier contains number of client side environments. This side takes input from the user and responsible for displaying maps. It includes no of web browsers linked with World.

Web browser is presentation tier of the web mapping architecture which involves mainly for finding the right web page and then making sense of its content (Dzbor et al., 2003). Uniform Resource Identifier identifies the information resource and may be a web page, image, video, or other piece of content (Ian et al, 2004).

Document Object Model support – According to World Wide Web consortium (W3C) DOM is a language –neutral interface which allows programs and scripts to dynamically access and update. It takes properties of every node of document tree and then allows deleting node, inserting new node, reordering exiting nodes and changing previous nodes. Google Maps, yahoo and Microsoft live and other web mapping sites apply a combination of Ajax, DHTML and SVG.

Scalable Vector Graphics support or image support – SVG integrates raster graphics, vector graphics, and the text. SVG supports, scripting and XML extension, animation, interactivity, mechanisms. SVG is ahead in providing high quality and providing interactive maps. SVG is supported most of the client side browsers nowadays.

2.4.2 Logic tier:

Logic tier of consist web server, application code and webGIS server. Web server takes user request and transfer output map result to the clients. Users request information is transfer to application code where the request of user is compiled, detects the user required information and sends the information to the map server. The map server detects which map is requested and sends information to data base. After receiving map data from data base server the map is processed. Editing, processing on map and generating output map are done this tier. Output maps are sending to the client web browser through the internet.

Web servers connect different software components with web server and a scripting language. Web server applications can communication with the API of a GIS, web server and with the spatial database of other applications. These Web servers are also very useful when we are developing complex web mapped applications, real time web maps or Web GIS.

2.4.3 Data base tier:

GIS and geospatial data are growing in importance for the Community, because they allow users to examine new types of information in new ways (Meyer, 2004). This tier is responsible for keeping map data in organized way. Relational database model is responsible for making relational database table for efficient retrieval of data. It sends and receives instruction and information through maps server and application code compiling centre. Map file stores the whole map in a file which is accessed by map server.

The figure 10 shows the web GIS architecture connecting Web GIS portal to geodata through internet in standard HTTP protocol using WFS and WMS.

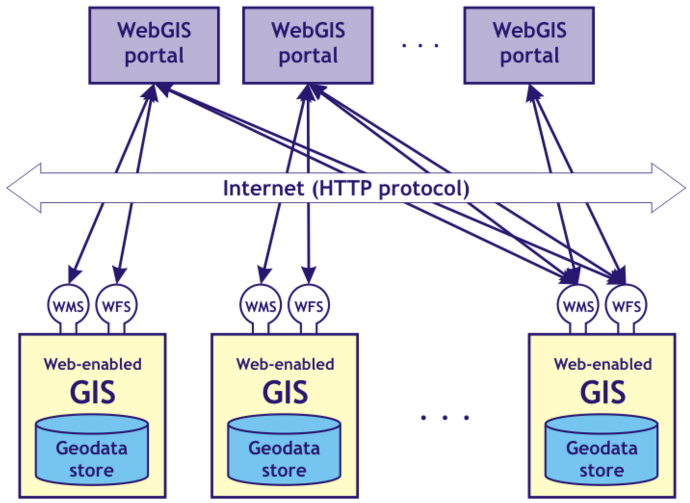

Figure 9 Schematic view of an overall WebGIS architecture (Milosavljević, et al)

2. 5 Available Web Mapping Technologies

Web mapping being one of the newest fields in Geographic Information system different software and technologies are being developed in both commercial as well as open source. For Commercial purposes commercial companies develop which are well documented may contain advance features but the price for that technology is high while open source system is developed by communities and can be used free of charge but they may contain poor documentation but open source system is developing rapidly with the involvement of large no of peoples. The major technologies involved in the realm of web mapping today are (Detwiler et al, 2009)

Commercial: ArcGIS Server by Environmental Research Institute (ESRI), GeoMedia WebMap by Intergraph, MapXtreme by MapInfo and MapGuide by

Autodesk.

Open source: GeoServer, MapServer, OpenLayers , Scaleable Vector Graphics (SVG), Adobe Flex (actually part open, part proprietary).

Public APIs: Google Maps, Yahoo! Maps, Microsoft Virtual Earth (2D), MapQuest's OpenAPI.

Globes: Google Earth, Microsoft Virtual Earth (3D), ArcGIS Explorer, NASA WorldWind

2. 6 Web technologies for web-based GIS

These open source software and tools was used to prepare web based GIS.

2.6.1 Web server

A web server accepts HTTP requests and serves the contents web pages to the client in the form of text, image, style sheet and scripts. There are different types of web server developed by different companies like IIS by Microsoft, Apache Tomcat, Sun Java system web server etc but Apache Tomcat is popular and widely used.

The figure 11 shows typical client server architecture with their role with browser as client.

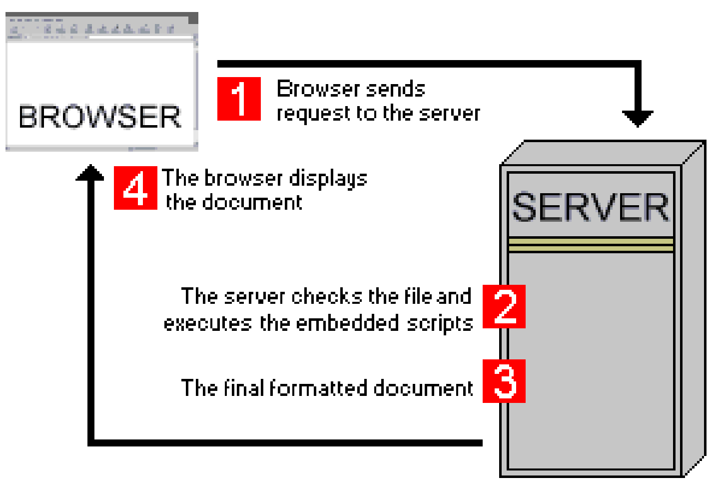

Figure 10 client Server Architecture, (Source: Webdevelopersnotes website, 2010)

HTTP clients use the TCP transport protocol to contact Web servers and request content. The client opens a TCP connection to the server, and transmits a HTTP request header that specifies the requested content.

The main task in the server is virtual hosting of many websites using IP, store large amount of data, run server side scripting to generate dynamic pages and limit the speed of responses to server more clients. The Web servers play a key role in satisfying the needs of a large and growing community of Web users (Pai et al, 1999).

2.6.2 Scripting language and JavaScript

A scripting language allows controlling one or more software application. Scripts are different from core programming language often interpreted from source code and embedded in other applications. In web based application scripts are embedded in HTML code. Clint side scripting are executed in client-side by web browsers whereas server side scripting the scripts runs on server side or application servers. The popular server side scripts are PHP, ASP and JSP. JavaScript is a client side object oriented scripting language is popular for developing client side application. It is developed by Netscape in 1995 and closely related with Java programming language and influenced with other programming languages but easier to program. It is dynamic, prototype based, weakly typed scripting language with first class functions.

2.6.3 Application Programming Interface

Application Programming Interface (API) which constitutes a language and message format is set of data structures, routines or protocols used by an application to communicate with other control program, communication protocol or operating system. Almost every application depends on the APIs of the underlying operating system to perform such basic functions as accessing the file system(Orenstein , 2000) APIs are implemented by writing function calls in the program, which provide the linkage to the required subroutine for execution. An API entails program module in computer to perform the operation or links to the existing program to perform the tasks[2].

Based on function and interaction the API also differs in the implementation in that environment. Generic APIs are full set of APIs included in library of programming languages. These API interacts with operating system, DBMS and other applications and facilitate interaction between users and the computers. Specific API only addresses defined specific problems like yahoo API, Google API. Language specific API operate in a specific language using syntax and components of that language where as language independent APIs can operate in different application and programming language. This feature of language independent APIs is required feature of service oriented API which doesn't limit on specific system, process or platform and useful for web services.

The API itself is largely abstract in that it specifies an interface and the behaviour of the objects specified in that interface. The API acronym may sometimes be used as a reference not only to the full interface but also to a single function or even a set of multiple APIs provided by an organization. Thus the scope is usually determined by the person or document that communicates the information. Based on the API documents, the user could learn and combine exist functions in the application more easily and efficiently.

2.7 Open Source and Open Standards

The OGC was founded in 1994 as an international voluntary consensus standards organization for geospatial data and web services. Now The OGC has more than 395 organizations specifically from government, Academia, industry, non-profit and research organizations (Openspatial, 2010). The Consortium was founded for providing open specifications at free of charge to acquire and/or Implement, thus provides standards-based interfaces for geographical data discovery, access, manipulate, Visualization and processing. The open specification provides information about a given specification as

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[2] http://www.pcmag.com/encyclopedia_term/0,2542,t=application+programming+interface&i=37856,00.asp

well as specific programming rules and advice for implementing the interfaces and/or protocols that enable interoperability between systems (Sanchez et al, 2007).

The OGC leverages existing efforts from other standards organizations such as the W3C, ISO, and the Organization for the Advancement of Structured Information Standards (OASIS), and builds upon them in reference to the spatial data domain (Kralidis, 2008). OGC standards depend on a generalized architecture captured in a set of documents collectively called the *Abstract Specification*, which describes a basic the data model for representing geographic features[3].

The members of abstract specification are developing and growing the number of specification and provides the reference model for implementation of the consortium specification. According to Kottman the main areas covered by the Abstract Specification include (Kottman, 1999 and Kralidis, 2008).

• Spatial Referencing by Coordinates
• Feature Geometry
• Features
•The Coverage Type
• Relationships between Features
• Feature Collections
• The OpenGIS Service Architecture

The OGC has an advanced and progressive development process for its specification which requires common consensus between specific working group members. These specifications developed, tested in OGC testing environments called “testbeds, and pilot project. Typical specification development takes place by defining, adopting, and publishing the specification document for vendors and others to implement (Kralidis, 2008).

[3] http://en.wikipedia.org/wiki/Open_Geospatial_Consortium

2.7.1 Open specifications standards

WMSA Web Map Service (WMS) is a standard protocol for serving geo-referenced map images over the Internet that are generated by a map server using data from a GIS database (Openspatial, 2009). The WMS contains a HTTP interface for requesting geo registered maps from different distributed databases. A WMS sends a request to server defining map layer and area of interest in the layer to be processed. The response to the request is one is generally rendered in a pictorial format such as PNG, GIF or JPEG, or occasionally as vector-based graphical elements in Scalable Vector Graphics (SVG) or Web Computer Graphics Metafile (WebCGM) formats (OGC, 2002) which can be displayed in browser.

WMS specifies different request types, out of which two are used by any WMS server

- GetCapabilities - returns parameters about WMS service, such as image formats which it can serve and provides the lists of one or more map layers available in the service.
- GetMap - with parameters provided its requests returns a map from the server. Clients are allowed to specify reference system, layers, geographic area and other parameters.

Some other supported Request types that WMS providers include:

- GetFeatureInfo
- GetLegendGraphic
- DescribeLayer

Web Feature Service: The OGC WFS defines interfaces for data access and manipulation operations on geographic features using HTTP as the distributed computing platform. This standard specifies operations to retrieve a description of the maps offered by a service instance, to retrieve a map, and to query a server about features displayed on a map (Hampe et al., 2006). Data manipulation operations include the ability to create, update, and query and delete spatial and non-spatial features. The user generates the request and sends it to a WFS server using HTTP. The WFS server then executes the request. Two encoding defined for WFS operations GET and POST. The figure 11 shows the relationship between different specifications defined by OGC.

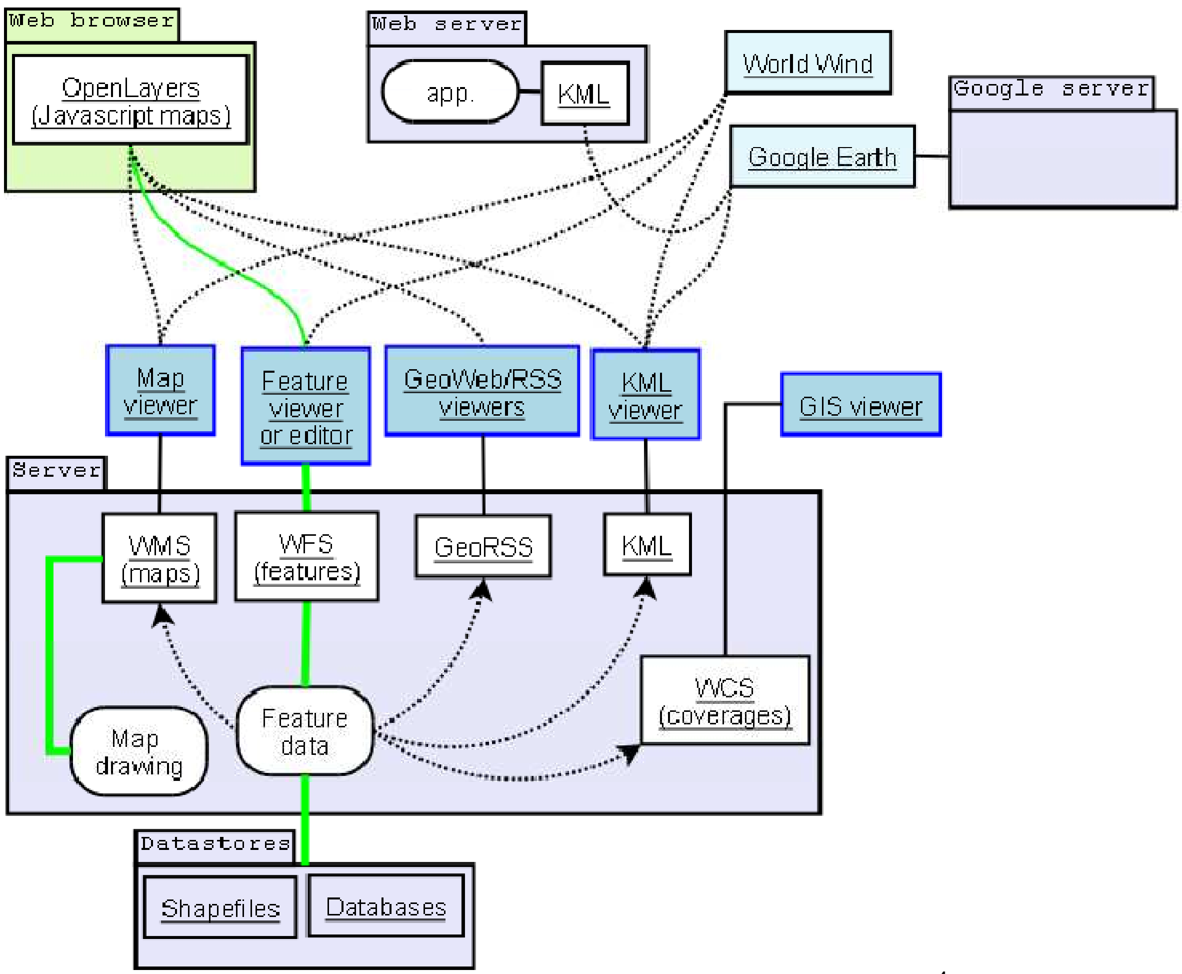

Figure 11 Relationship between clients/servers and some OGC protocols [4]

A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more geo-registered map images (returned as JPEG,

[4] (Source: http://en.wikipedia.org/wiki/Open_Geospatial_Consortium Retrieved February 5, 2010)

PNG, etc) that can be displayed in a browser application (Openspatial, 2010). The interface also supports the ability to specify whether the returned images should be transparent so that layers from multiple servers can be combined or not. Therefore, it allows for a smooth integration of different (raster or vector) maps in web mapping applications over the Internet (Schütze 2007).

The publishing way of traditional WebGIS includes raster-map mode and vector-map mode. Recently, with the increasing popularity of global on-line web mapping applications (e.g. Google Maps, Microsoft Virtual Earth, Yahoo Maps), the raster Tile-Map mode replaces vector map gradually. A tile caches service has a set of map images that have been pre-rendered for rapid display (Quinn et al, 2008). Map tiles are a set of map images that have been pre-generated based on geographic vector data and the adoption of tile-map technique in the developed system dramatically decreases the loading time consumed for high quality image visualizations (Haiting et *al*, 2009). Map tiles are extremely efficient and capable of running large images over the internet. In Google maps commonly have zero to twenty pyramid layers covering entire globe.

2.8 Geovisualization

Geographic visualization(Geovisualization) is a tool and a technique which supports spatial data using interactive visualization in research related field which integrates disciplines such as computer science, human-computer interaction design, cartography, cognitive sciences, graphical statistics, data visualization, information visualization and image analysis (Dykes et al, 2005). It builds on the established tenets of map production and display (Goodchild et al, 2005).

Closely related with other fields of scientific visualization (MacEachren, and Kraak, 1997) and information visualization (Stuart et al. 1999), Geographic visualization focuses on knowledge construction through knowledge storage and knowledge transmission (MacEachren, and Kraak, 1997). To accomplish this, geovisualization communicates with spatial information and combines with human vision and domain expertise, which allow data exploration and support decision-making processes (Jiang et al. 2005 and MacEachren, 2004).

Static maps have a limited exploratory capability while the animated maps spans the spectrum of disseminating spatial knowledge to a wide audience to data exploration for knowledge discovery by experts(Harrower, M., 2008) example of such animations are weather maps animation in television. It also allows more interactive options like changing visual appearance, zooming in or out and explores more layers (Jiang et al. 2003). Geovisualization characterizes a further improvement in cartography that takes advantage of the modern computers power to render changes to a map, allowing users to adjust the mapped data on the fly (MacEachren and Kraak, 1997).

Owing to its roots from cartography, geovisualization supports to visualize other non-geographic attributes from other fields by the way of the map metaphor in the domains of information and knowledge visualization (Jiang, and et al. 2005).

3 .Applications used for implementation

3.1 Openlayers

Openlayers is an OSGeo supported project and works in browser (JavaScript/AJAX) application for accessing and displaying map tiles, features and markers from different and wide range of data sources. Open source JavaScript library is released under a BSD-style License for displaying a dynamic map in web browsers and provides the functionality of managing and manipulating data in the browser. It is open source hence it can be used for re-development, re-use, and updating. It supports different data formats and web services which includes Keyhole Markup Language (KML), Geography Mark-up Language(GML), WMS/WFS Services, Web Map/Feature Services, Representational State Transfer requests(REST), Geographic JavaScript Object (GeoJSON), GeoRSS, TileCache web accessible caches and other many commercial and free web map services like Google maps, Yahoo! Maps , Microsoft bing map, World Wind, etc. OpenLayers allows using JavaScript to display feature information on a map. This feature information might come directly from a UI, or GeoJSON feed, or it might originate from a GML or KML data source (Ganesan, 2009)

3.2 PostGIS

PostGIS isn't only a geographic data storage extension. It has capabilities from other projects that allow it to manipulate geographic data directly in the database. The ability to manipulate data using simple SQL sets it ahead of many commercial alternatives that act only as proprietary data stores. Their geographic data is encoded so that only their proprietary tools can access and manipulate the data (Tyler, 2005).

PostGIS is popularly used in map data storage and manipulation. It is ideal for multi tasking applications for accessing information simultaneously. Other GIS application and mapping tools can interact with PostGIS. GeoServer uses the OGC Transactional WFS (WFS-T) standard for accessing PostGIS and other formats. A PostGIS function also returns Scalable Vector Graphics (SVG) formats.

A PostGIS spatial include many of the functions similar to normal databases like using SQL commands to accessing data. It also includes the PostGIS geometry data which are used to create, manipulate and summarize new spatial data. Many PostGIS functions allow for a range of manipulation as well as conversion into different data types (Tyler, 2005).

3.3 GeoServer

GeoServer is a Java-based server that allows users to view and edit geospatial data. Implementing the Web Map Service (WMS) standard, GeoServer can create maps in a variety of output formats. Openlayers, a free mapping library, is integrated into GeoServer, making map generation quick and easy. GeoServer is built on Geo-tools, an open source Java GIS toolkit (Geoserver, 2010). There is much more to GeoServer than nicely styled maps, though. GeoServer also conforms to the Web Feature Service (WFS) standard, which permits the actual sharing and editing of the data that is used to generate the maps. Others can incorporate your data into their websites and applications, freeing your data and permitting greater transparency (Geoserver, 2010)

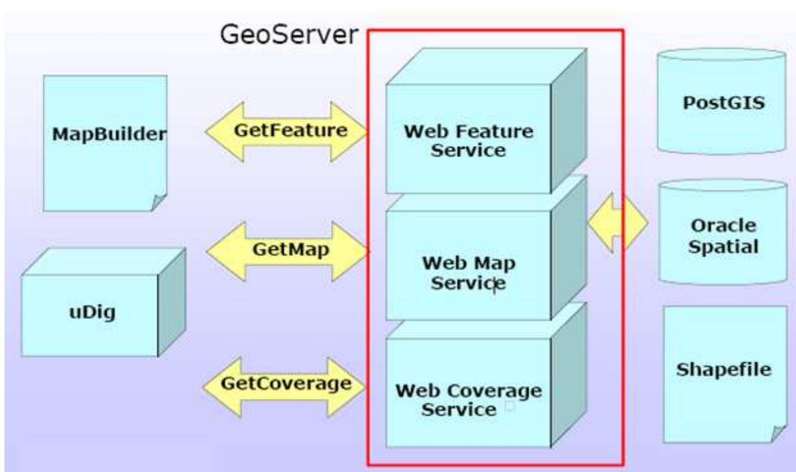

Figure 12 Geoserver services architecture (Source www.geoserver.org)

GeoServer is the reference Implementation of the WFS and WCS standards, as well as a high performance certified compliant WMS. GeoServer forms a core component of the Geospatial Web. Compared to the MapServer, GeoServer supports the most of GIS functions rather than only publish spatial data (Zhelu, 2009).

3.3.1 Configuration Design of Geoserver

The Web Based Configuration Design provides a series of design goals for updating the GeoServer Configuration System. Which Separate the Configuration Model from the GeoServer Application, Build a Struts Web Interface against the Configuration Model, allow XML persistence of the GeoServer Application Configuration state, Maintain the existing configuration file format To meet these requirements, Layered Architecture was proposed (Figure 14).

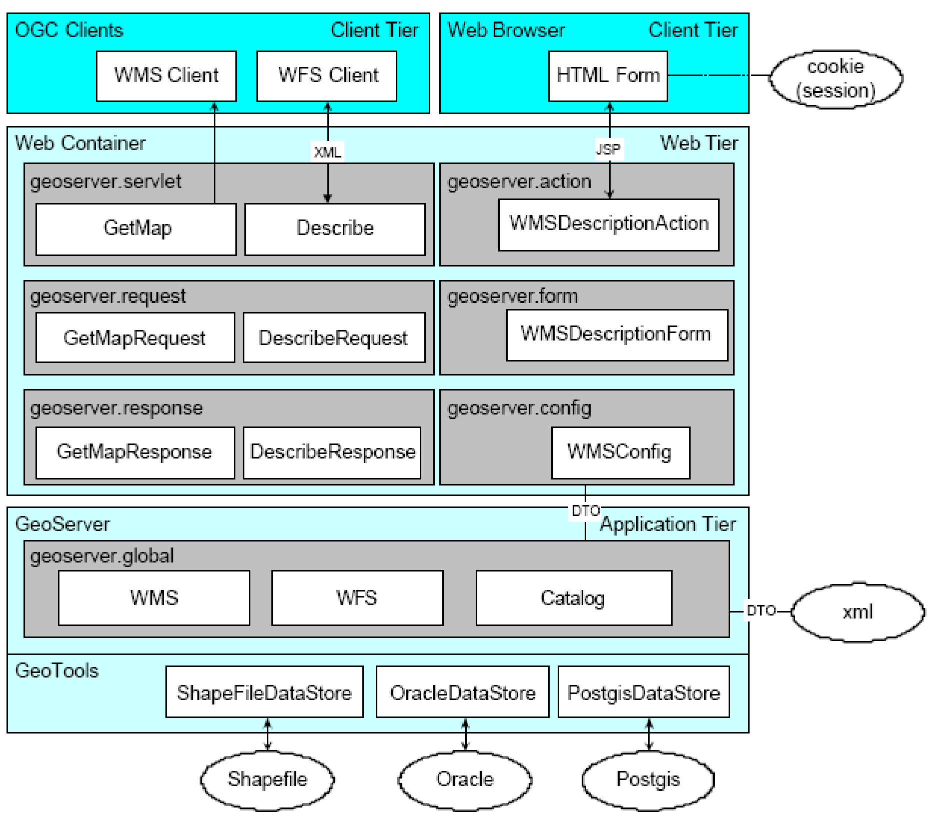

Figure 13 Geoserver Layer Diagram(source, geoserver.org,2010)

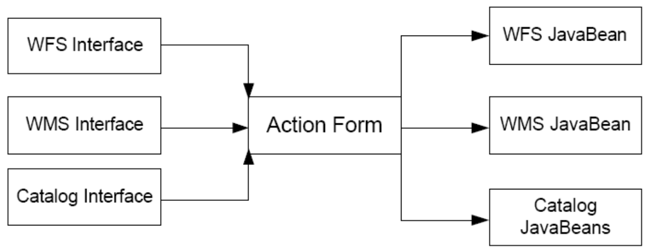

Figure 14 Interface flow Diagram

3.4 uDig

uDig is a Desktop GIS software produced by community. Canadian-based consulting company called Refractions Research is taking responsibility of development. It is written in java based on Eclipse Rich Client technology and released under GNU Lesser General Public License. It is user friendly and Internet oriented consuming standard WMS, WFS, WCS, KML, GeoRSS and tiles for geospatial web services (Refractions, 2009). It supports PostGIS, ESRI shape file natively.

According to refraction .net, the developer of the software, the aim of the udig is to provide a complete Java solution for desktop GIS data access, editing, and viewing.

- User friendly environment
- Desktop located running in all operating system environment
- Internet oriented operation supporting most of the components of web GIS.

Beside these, following software or applications are used for their respective purposes.

Openjump
ArcMap 9.3.1
Adobe Action script 3.0(Flash)
Google Earth
Tilecache
Surfer (Golden Software Inc.)
PHP
WAMP server

4. Materials and Methods Used

This chapter provides general information about methods and material used in the thesis.

4.1 Data used

Input data	**Description**	**Source**
Boundary map	Carta Administrativa Oficial de Portugal (CAOP)	Instituto Geográfico Português.
Weather station data	Weather data	www.cotr.pt

Table 2 Data Used

The weather data from weather stations are published regularly on the website www.cotr.pt/sagra. Minimum temperature, maximum temperature, average temperature, solar radiation, average grass temp, precipitation and calculated ETO are published which are required to determine the crop water need. Weather data were collected from the website.

From Carta Administrativa Oficial de Portugal (CAOP) the boundary of study area is selected.

4.2 Requirement analysis

The primary objective of developing web map is to visualize weather information which is responsible for crop water requirements. Temperature, solar radiation, relative humidity, precipitation are selected as primary components responsible for crop water needs. From these values evapotranspiration and reference evapotranspiration can be calculated from equation recommended by FAO. Developing weather maps based on daily weather data requires frequent update and it will not be useful for decision making process as well. Weekly, monthly or annual maps will be more useful for deciding irrigation and irrigation planning. To meet this requirement, average weather values were calculated from daily weather information for making weather maps. It should contain basic map components to operate and interpret. To visualize and analyze the trend of changing weather parameters and evapotranspiration animated maps will be very helpful. Monthly average weather data for year 2008 and 2009 were selected to animate weather maps which should contain basic control functions to display maps interactively. Another requirement is to store old maps so that they can be retrieved later. To fulfil the requirement a web map data gallery has to be created where user can easily store maps and access easily.

4.3 Data processing

The weather station data are produced on a daily basis and it is inconvenient to produce maps by daily updated data as it is not automatic. The data are averaged on a weekly, monthly and yearly basis and merged in one sheet containing all weather points. Precipitation, mean temperature, solar radiation, grass temperature, reference evapotranspiration ETO are selected for this process. The entire database was more than 67 MB containing daily weather information from 2001.

4.4 Making weather Maps

The boundary of study area was identified and created the boundary map from the shape file Carta Administrativa Oficial de Portugal (CAOP) version 2008.1 which was obtained from Instituto Geográfico Português (www.igeo.pt). The weather station points are converted to point shape file. The boundary, water body, and point shape files are loaded into PostGIS database using Openjump. These shape files are loaded and configured in Geoserver. But the Geoserver doesn’t have feature of geo-processing like kriging interpolating of point data value over the surface. According to Wolf and et al. (2009) Kriging is intensive processes currently not available in Geoserver. Web processing service (WPS) is expected to solve this problem. The WPS module is currently under development and not supported as part of the standard GeoServer configuration (Geoserver, 2010). The SLD script is limited to basic functionality only not for spatial interpolation like kriging.

For making interpolated weather map of evapotranspiration, precipitation, relative humidity, temperature, grass temperature and solar radiation Geostatistical extension of ArcGIS 9.3.1 and surfer from Golden software are used to develop interpolated maps. While exporting to vector format it only stores the counter or filled counter but predefined colour and respective value will be lost. Whereas the raster format preserves coordinate system of the area only in Geotiff format using 'world file'. This procedure is repeated for all weather parameters.

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4.5 Configuring Geoserver

To serve map data to the internet we need to install GeoServer on a server connected to the Internet or localhost. It requires web serving software like Apache web server. Beside this Geoserver also requires more other components.

1. Servlet engine. A servlet engine called Jett which comes with Geoserver. There is another popular servlet engine called Tomcat.
2. A Java development kit (JDK). To install the Geoserver Java development Kit is required. We can download from Sun Microsystems freely.

GeoServer has a web interface where we can configure data. In this web development process Geoserver is installed in localhost. The default servlet port used by Geoserver is 8080.

The information flow in Geoserver is shown in the figure 16.

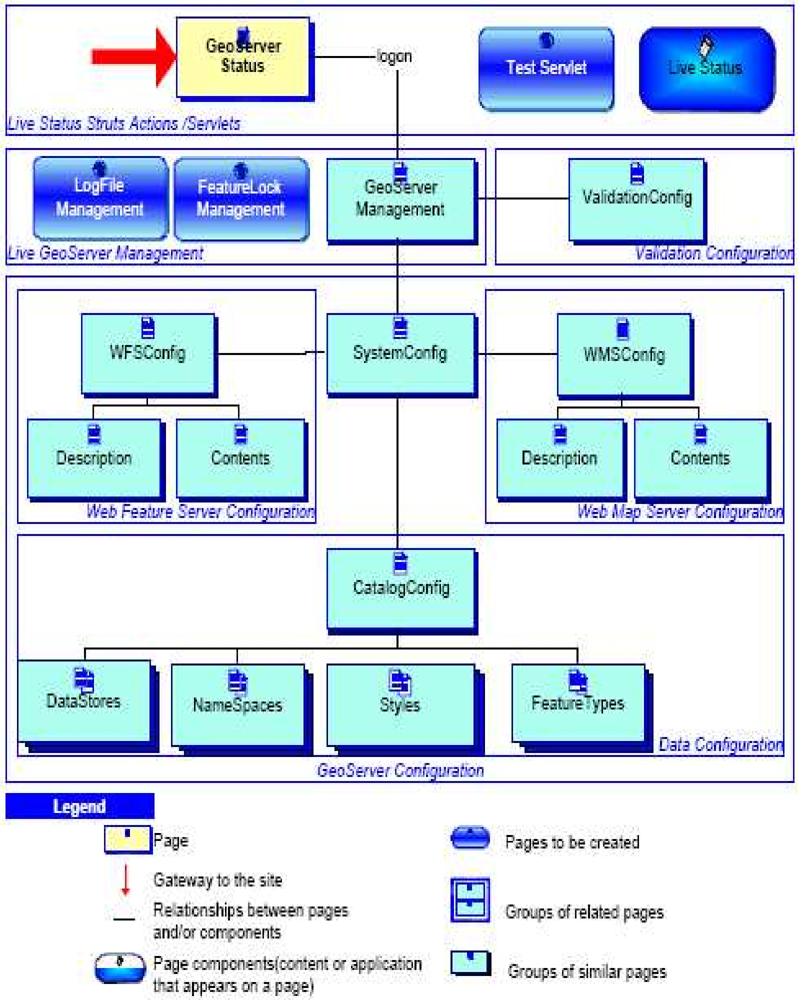

Figure 15. Information flow diagram in GeoServer ((Source: Refraction Inc, 2010)

4.5.1 Adding data to PostGIS table

Loading data to PostGIS can be done by two methods

1. Using Loader utility: the shp2pgsql command of PostGIS can be used to convert shape file data into SQL format. The Command used to convert shapefile to sql file is as follows

    shp2pgsql file.shp table_name > file.sql

    Loading data in PostGIS

    psql –u username –d dbname –f file.sql

Change SRID
Select updategeometrysrid('table name ', 'tem_col', <new_srid>);

2. Another way to convert shape file to SQL is using Openjump. It is also open source software can be freely downloaded. Using Openjump shape file is converted to SQL by loading shapefile file> Load datasets from file and selecting the required shape file. Then the SRID (Spatial Reference System Identifier) is defined as 4326.

4.5.2 Adding Data to GeoServer:

New data can be added in Geoserver using config> datastore>New. Geoserver generally takes shape files as input. In new feature data set selected PostGIS as new feature dataset description. Feature data set ID is given to the shape file. In new Feature Data Set Editor Panel, name space is defined as TOPP. Loading the data from database, localhost was defined as host port 5432 which is the default port of postgreSQL. To define the new feature type, new feature type as polygon was defined in config>data>featuretype>new. New SLD is created to the datasets. The main purpose is display overlay maps in Google maps or Bing maps so the SRS is defined as 4326.The SRS WKT (Spatial reference system well known text) is shows the projection and coordinate of the data sets. By selecting bounding box it generate the minimum and maximum longitude and latitude of the data. Completing this configuration step data will be stored in Geoserver.
In this application most of the maps are created using interpolation in ArcGIS, exporting interpolated maps into shape file loose predefined colour and output will not represent the actual map. To solve this interpolated maps are exported into GeoTiff format which preserve the projection co-ordinate system of the maps. The configuration of Geotiff images is different from the shape files in Geoserver. Geoserver WCS coverage is used to store coverage information of raster image files. The raster images are saved in geoserver_install/data_dir/coverages/ directory Geoserver installation directory.

‘Coveragestore’ of Geoserver a new coverage data store tagged image file format (GeoTIFF) with Geographic coordinates was selected with a required coverage data set

ID. To create coverage of the Geotiff image the style raster is selected in coverage editor. The SRS and the bounding box parameters are configured for raster image.

Geoserver creates KML file which is modified to animate point location and corresponding value with time using time stamp. The KML script can also shows weather information with time. It can be viewed in standard Google Earth with changing weather values with time.

4.6 Working with open layers

Openlayers is a Java script library and HTML is used to develop web interface and connect WMS and WCS. GeoServer is connected to Openlayers client and CSS defined for the page to display in browser. Shape file of water body, boundary and point are loaded from database which can be fetched by GeoServer to Openlayers. Weather station points were also determined giving longitude and latitude which can show weather parameters value when clicked. It can be easily updated and modified through database meanwhile Openlayers also accepts marker points through standard text page which can be changed without any knowledge of database and GeoServer. All the WMS layers were added to the map as overlay layer using map. Base layer were reserved for yahoo, Google, Bing, Openstreet maps and their APIs were added in using in the script. Basic mapping components were added using

```
map.addControl(new OpenLayers.Control.PanZoomBar());
map.addControl(new OpenLayers.Control.MousePosition());
map.addControl(new OpenLayers.Control.MouseDefaults());
map.addControl(new OpenLayers.Control.KeyboardDefaults());
```

4.7 Tile cache

TileCache provides a Python-based WMS-C/TMS server, with pluggable caching mechanisms and rendering back ends. TileCache requires write access to a disk, the ability to run Python CGI scripts, and a WMS to be cached. This creates local disk-based cache of any WMS server, and use the result in any WMS-C supporting client, like Openlayers, or any TMS supporting client. The TileCache library can speed up access WMS by factors of 10-100, or more (Metacarta, 2008).

GeoServer supports TileCache as a caching layer in front of the WMS. For non-dynamic mapping data in GeoServer using it will help users an experience that comes close to matching Google Maps in terms of responsiveness and usability (Geoserver, 2010).

TileCache client supports multiple different rendering backend. Each rendering backend also supports the ability to draw 'metatiles', where a large tile is rendered (Metacarta, 2008) and then chopped into smaller tiles using the Python Imaging library or Maptiler.

- MapServer -- render a tile using Python mapscript.
- Mapnik -- render a tile using the mapnik Python bindings.
- Cascading WMS -- fetch a tile from a remote WMS service
- DiskCache -- Store files on disk.
- MemoryCache

Tile cache’s configuration should do in ‘tileche.cfg’ file. Then customization of tile cache in Geoserver and web client (Openlayers) is required. I used Openlayers WMS for displaying tiled maps.

4.7.1 Openlayers for Tiled map overlay

Openlayers can create TMS overlay using map tiles. Map tiling technique is initially used by Google Map and becoming popular as it is faster to display.   Tiles are part of map of equal size. For displaying map in Openlayers Java script API for standard Google maps, Bing map and Openstreet map were imported in Openlayers API Openlayers.js. Boundary area for study area is defined as -12.2630619706, 35.394754657, 1.84357280352 and 41.0549698217. Projection system is defined as EPSG and 900913 new projection system for is defined as EPSG 4326 for WGS84. Then after zoom level is fixed from minimum 2 to maximum 9 level to display map, mapping controls like layer switcher, zoom panel , pan zoom bar are added.

```
}

function osm_getTileURL(bounds) {
    var res = this.map.getResolution();
    var x = Math.round((bounds.left - this.maxExtent.left) / (res * this.tileSize.w));
    var y = Math.round((this.maxExtent.top - bounds.top) / (res * this.tileSize.h));
    var z = this.map.getZoom();
    var limit = Math.pow(2, z);

    if (y < 0 || y >= limit) {
        return ;
    } else {
        x = ((x % limit) + limit) % limit;
        return this.url + z + "/" + x + "/" + y + "." + this.type;
    }
}

function overlay_getTileURL(bounds) {
    var res = this.map.getResolution();
    var x = Math.round((bounds.left - this.maxExtent.left) / (res * this.tileSize.w));
    var y = Math.round((bounds.bottom - this.tileOrigin.lat) / (res * this.tileSize.h));
    var z = this.map.getZoom();
    if (this.map.baseLayer.name == 'Virtual Earth Hybrid') {
      z = z + 1;
    }
    if (mapBounds.intersectsBounds( bounds ) && z >= mapMinZoom && z <= mapMaxZoom ) {
      return this.url + z + "/" + x + "/" + y + "." + this.type;
    } else {
      return ;
    }
}
```

Figure 16 part of code for accessing tiles from server (prldal, 2008)

```xml
<?xml version="1.0" encoding="utf-8"?>
    <TileMap version="1.0.0" tilemapservice="http://tms.osgeo.org/1.0.0">
      <Title>temperature</Title>
      <Abstract></Abstract>
      <SRS>EPSG:900913</SRS>
      <BoundingBox minx="36.96267898427022" miny="-9.45950473892615" maxx="39.58645010355162" maxy="-4.68959974215275"/>
      <Origin x="36.96267898427022" y="-9.45950473892615"/>
      <TileFormat width="256" height="256" mime-type="image/png" extension="png"/>
      <TileSets profile="mercator">
        <TileSet href="2" units-per-pixel="39135.75847500000200" order="2"/>
        <TileSet href="3" units-per-pixel="19567.87923750000100" order="3"/>
        <TileSet href="4" units-per-pixel="9783.93961875000060" order="4"/>
        <TileSet href="5" units-per-pixel="4891.96980937500030" order="5"/>
        <TileSet href="6" units-per-pixel="2445.98490468750010" order="6"/>
        <TileSet href="7" units-per-pixel="1222.99245234375010" order="7"/>
        <TileSet href="8" units-per-pixel="611.49622617187504" order="8"/>
        <TileSet href="9" units-per-pixel="305.74811308593752" order="9"/>
      </TileSets>
    </TileMap>
```


Figure 17 Tile Map cutter generated resource xml code

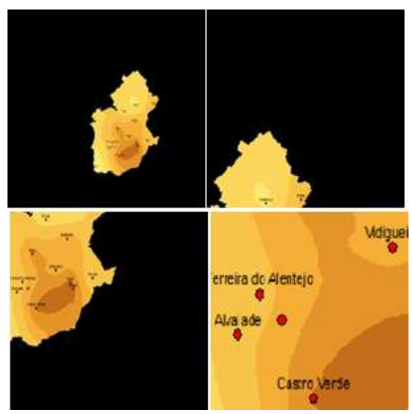

Figure 18 Map Tiles of Different Zoom level of study area

Figure 19 shows map tiles from 'diskcache' for different zoom level. Same size of tile represents different size of area depending upon map zooming.

4.8 Animating maps

Animation provides important information for analysis of temporal data. Sophisticated animation for weather is created based on repetitive collection of weather parameters. Each key frame is loaded with one temporal information, precipitation, evapotranspiration and temperature maps and controlled by Actionscript controller commands to display, smoothly in the browser. Adobe Flash Actionscript 3.0 is used which supports ArcGIS native maps directly for further processing to display interactively. Control commands like play, stop, and start are added.

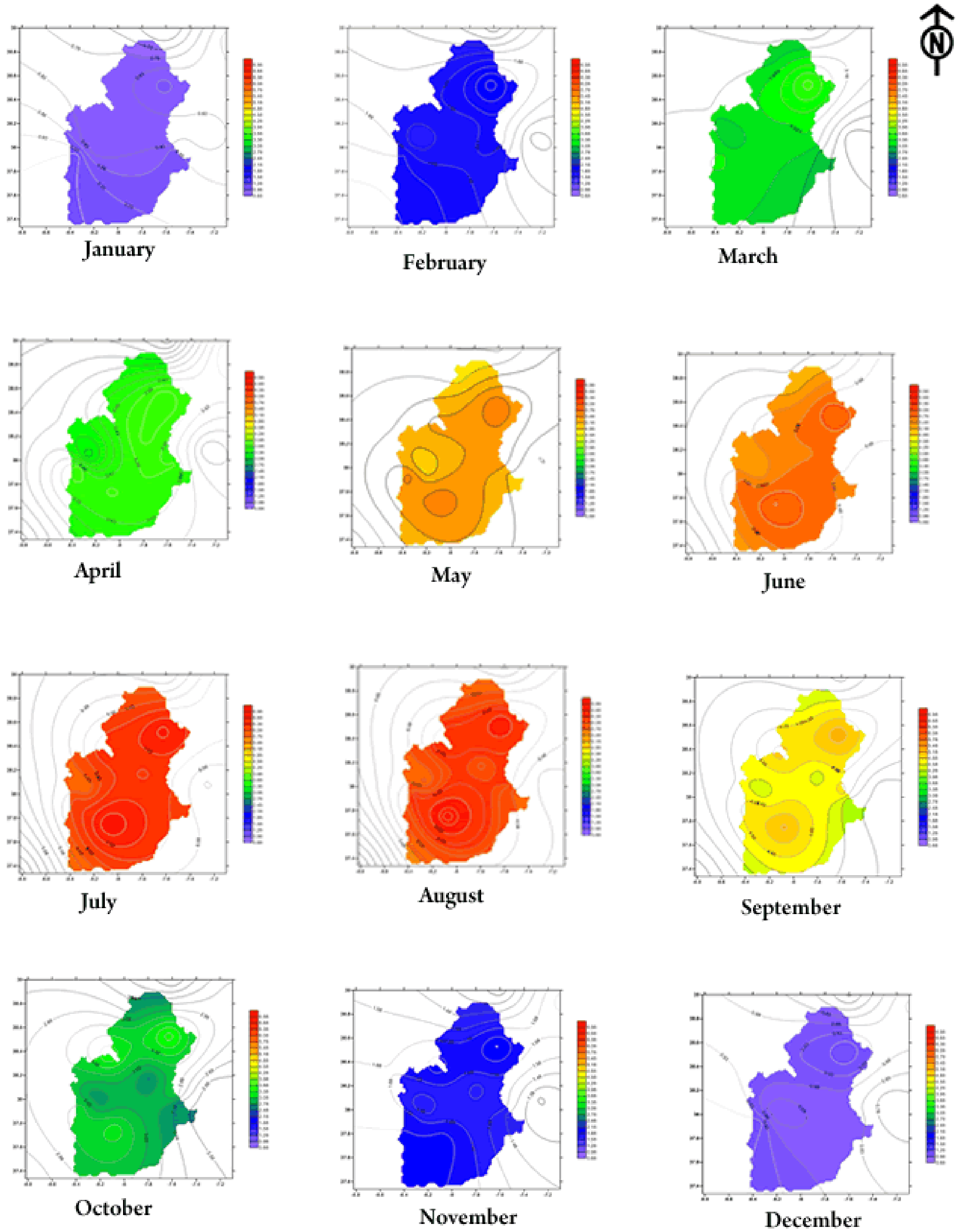

Figure 19 ETO maps in different months

5. Implementation and Results

The web interface contains main window, information window, and legend and information window panel. The left panel provides clickable icons for different parameters of weather. In Openlayers client we can visualize map in different base layers, overlay the map, switching base maps, zooming.

Weather station information, description and different layers of water body, boundary, location, can be viewed by clicking the overlay layers. Following figure 21 shows weather station markers showing corresponding information which is visible on clicking the checkbox of overlay.

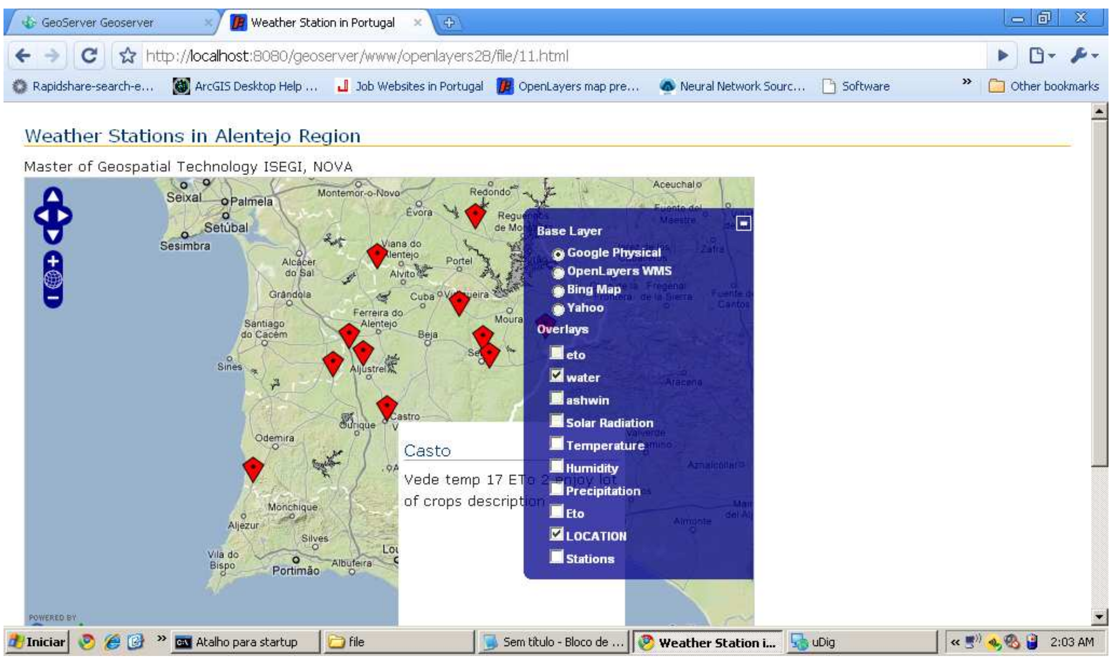

Figure 20 Weather stations showing station information

Weather as well as evapotranspiration maps from PostGIS database which were exported from ArcGIS shows only single colour contour or single colour shades and didn’t provide appropriate information. Using udig, a desktop application, the style of the map was changed and displayed. Exporting interpolated maps in raster format will preserve the predefined colour and Geotiff raster preserves the coordinate system. The

Geotiff images were tiled using automatic tile cutter script and displayed using tile cache technique, which significantly improved the loading performance.

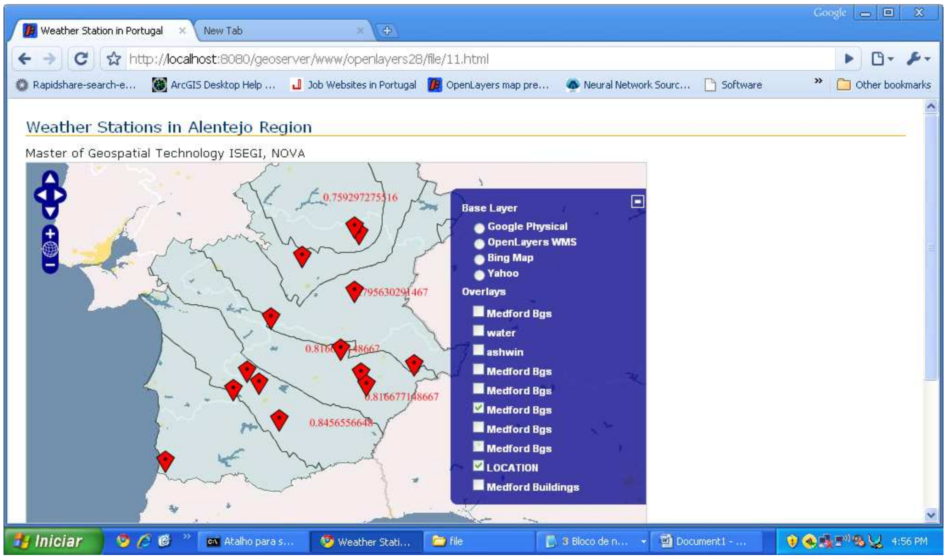

Figure 21 Contour maps using Vector layer from database

Figure 22 shows vector layer displaying the contours for ETO, natively it just shows simple contours only. Using udig it can be changed into filled contour map.

.

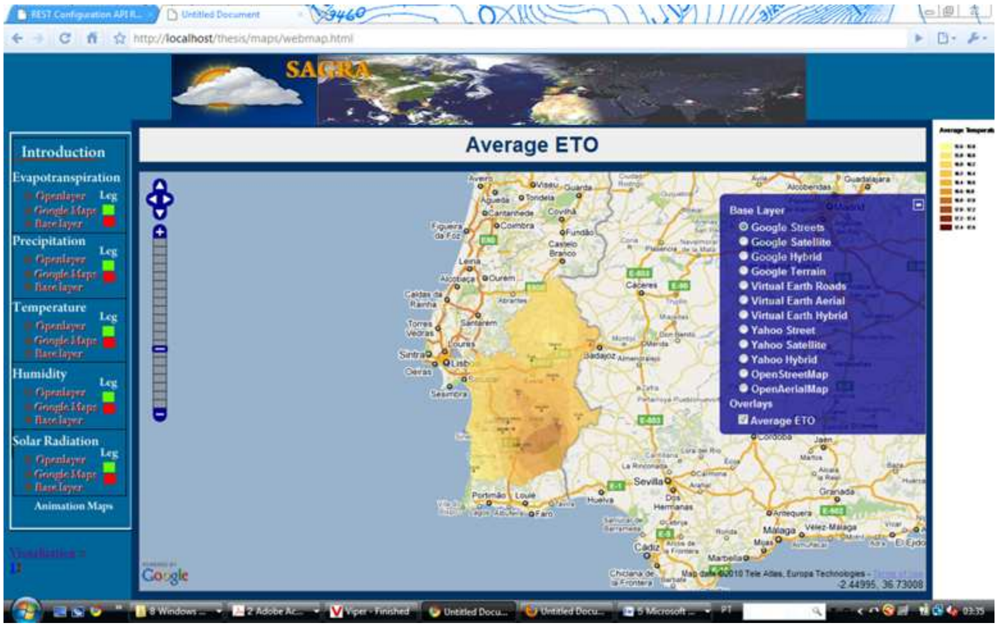

Figure 22 Web interface showing overlay with online base layers (Google, yahoo, virtual earth)

Fig 23 shows the weather map is overlaid with yahoo, Google, and Microsoft and Openstreet maps. These give users to see the required area with extra information from overlaid layers.

This shows average Evapotranspiration is higher near Beja area.

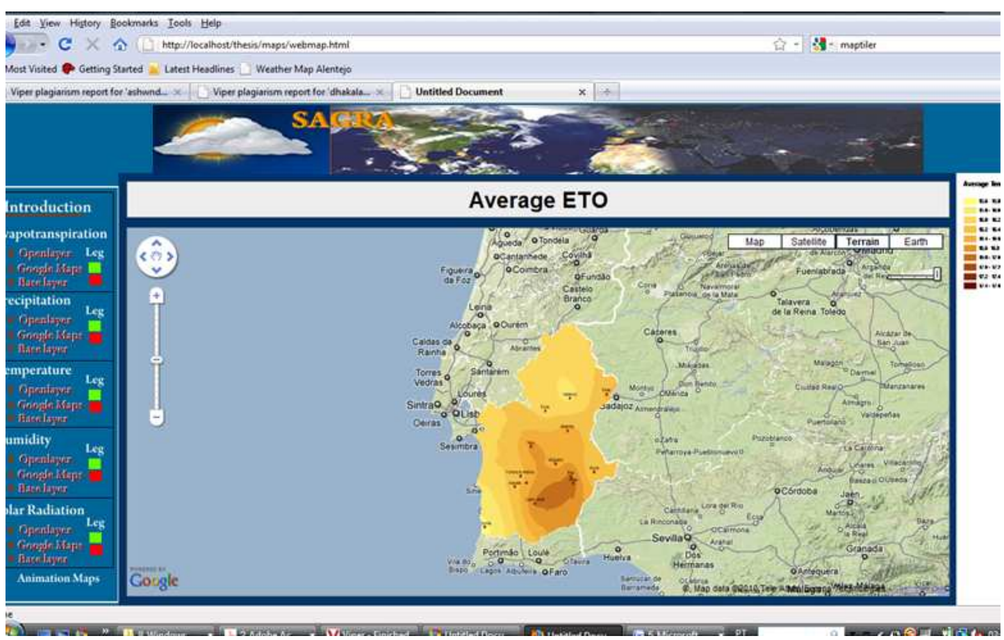

Figure 23 Average Evapotranspiration in Google maps

Animated weather map contains control icons stop, play and back. Figure 25 shows layout page of animation. Different animated maps can be viewed by clicking labels on the top. It shows contour lines and filled contour lines inside the study area. The legend is fixed so that the change in weather parameters can be compare between different maps at different time.

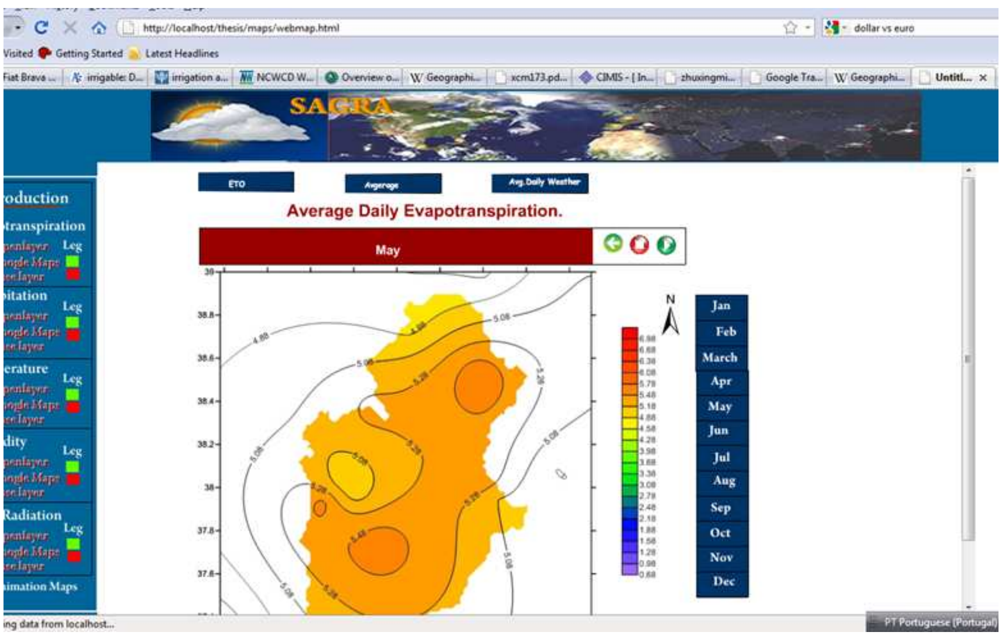

Figure 24 Animation Page layout

5.1 Map Gallery

For analysis of the weather for decision making process old maps are required. To address this requirement a web map gallery was developed. Maps from last week or month or year provide useful information for analyzing the weather and crop water requirement. The web map gallery is user friendly the web map gallery is programmed in PHP and used WAMP server version 2 as web server.

PHP code was written to web map gallery. For this Graphics Draw (GD) library was used with PHP to make thumbnail of images. GD is an open source library for the creation of images by programmers which is written in C. GD helped to create images of different formats and size. A map upload page was also created so that users or administrator could add maps .

This PHP script automatically creates its own thumbnail to show the index of stored maps. Small thumbnail of size 150 * 150 pixel size shows the index of map. The number of thumbnail automatically updated according to the no of stored maps. Maps can be sorted based on name, time of creation i.e. can be sorted in ascending or descending order and old map and new map. Clicking thumbnail will show the full map with date of creation, description of the map which is very helpful to know the map and its information.

A map uploading interface was created, so nothing has to be configured to store map in the server. Thumbnail will created automatically and map will store in current directory. We can change the map directory but default directory is ‘current map directory’. Available map directories are displayed in the interface of the map. Figure 26 displays the overall map index which are stored in the map gallery. Similarly the figure 27 shows the selected map in full screen.

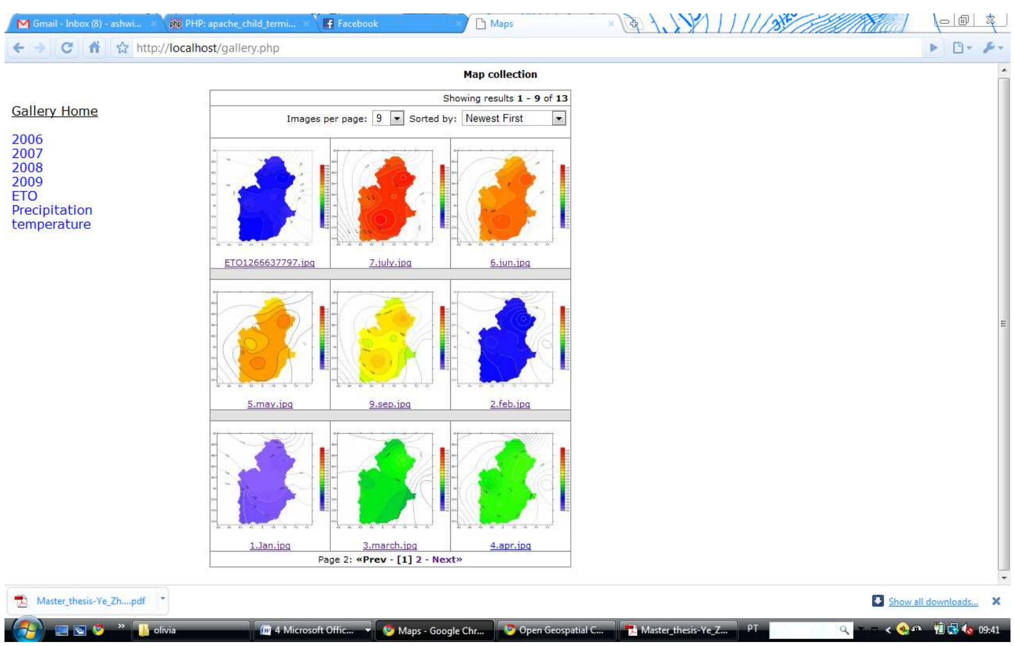

Figure 25 Map display interface

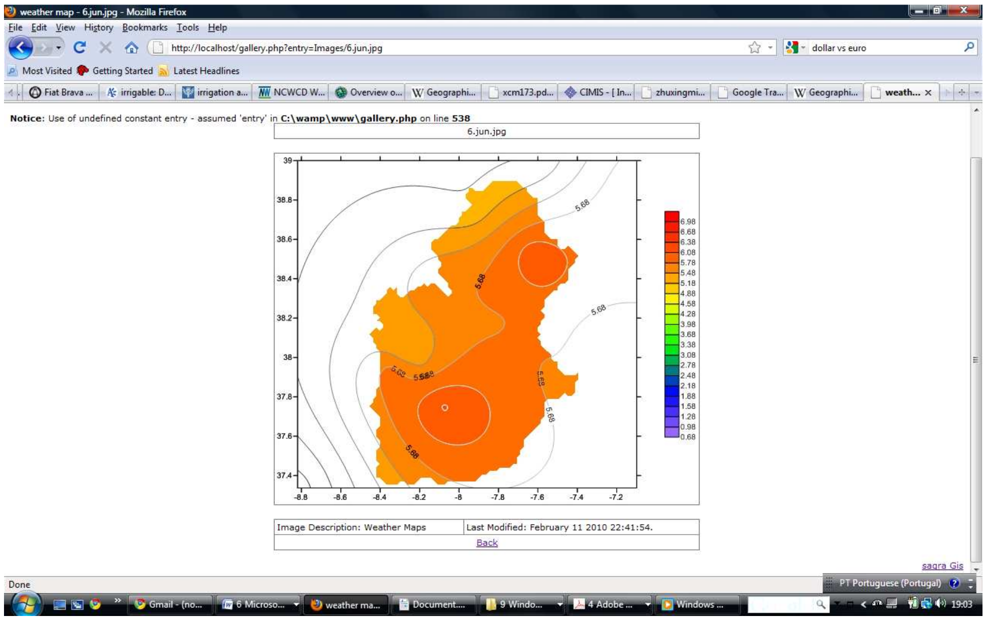

Figure 26 Full Map display interface

Fig 27 shows full image display with information of date of cration and description of the Map.

7. Limitations and Further Development

The development and visualization of weather map is a complex process that requires frequent update and the parameters change continuously. Several locations with changing parameter values make it more difficult to generalize. For the use of irrigation decision management maps can be produced on weekly or monthly basis.

Development of interpolated maps using open source software is more complex. Most of the components supporting for geo-processing are under development.

Software limitations: Web Processing Service is unsupported in Geoserver but developing communities are trying to develop and may be available soon. Web processing service can be very useful to make weather maps in real time environment. Automatic weather stations provide weather parameters automatically and web processing component of web server can interpolate over the boundary which can be automatic without doing any manual updates.

Moreover, PostGIS is very useful extension of PostgreSQL for handling and processing of spatial database points, line, polygons, multi line strings multi polygons and other geometrical objects. But it does not support raster file like GeoTiff. Due to this limitation maps cannot be stored in database and access in Openlayers client. This is the major limitation of the PostGIS. Some attempts are going on to make PostGIS to support raster images and this limitation can be solved (postgis.org, 2010).

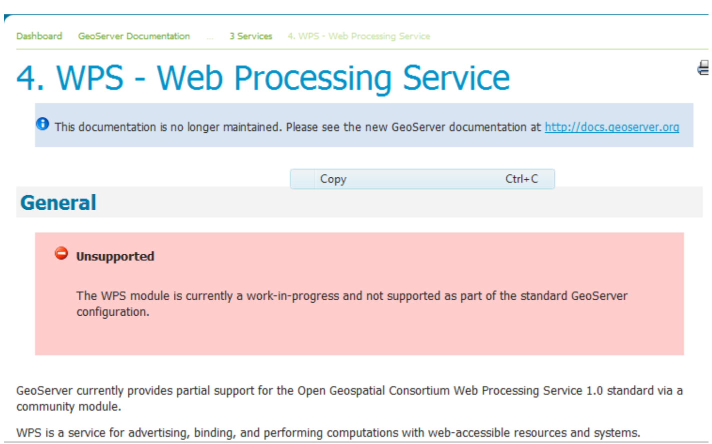

Figure 28 WPS unsupported

8. Conclusion

The evolution of web and its rapid expansion in the last decades created a new platform for information sharing with enormous potential and possibilities and increased efficiency and speed. Due to enhanced features of sharing, accessing and manipulation Geographic Information System also started growing in new platform through traditional desktop application to web.

The spatial and temporal variability may create problem to traditional Irrigation management support system, GIS can be solution in this regard. Integration of GIS with web can be a good example of information sharing and visualization.

In this thesis work different methods of publishing maps over the web are implemented. Average weather data are used to make web map using open source software and specification. For this Geoserver and Openlayers are used while PostGIS is used as database. Surfer and Adobe Flash with Actionscript are used to make time series monthly animated maps. These animated maps will be very useful to analyze the change pattern of weather. PHP with WAMP server is used to store and display maps. Tile cache mapping is new in web mapping but it is becoming popular due to its responsiveness and usability.

However, web mapping applications are not well developed like desktop GIS applications especially for interpolation of point data. Research and developments are on their way and will available soon.

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APPENDICES

1 Weather data

SAGRA-Net

Username: ashwindhakal
EMA: Herdade do Outeiro

Data	Tmed (ºC)	Tmax (ºC)	Tmin (ºC)	HRmed (%)	HRmax (%)	HRmin (%)	RSG* (kj/m^2)	DV (graus)	VVmed (m/s)	VVmax (m/s)	P (mm)	Tmed Relva (ºC)	Tmax Relva (ºC)	Tmin Relva (ºC)	ET0 (mm)
01-01-2010	10,56	16,22	6,82	83,50	98,69	54,91	9.192,80	253,50	1,39	7,23	0,60	11,01	13,64	9,49	1,00
02-01-2010	10,26	15,39	4,99	89,98	100,00	74,07	4.644,60	141,50	2,29	7,73	0,00	10,86	13,19	8,83	0,80
03-01-2010	13,24	15,38	11,65	95,82	100,00	85,72	1.171,96	159,90	2,78	6,95	13,33	12,42	13,59	11,08	0,40
04-01-2010	13,17	17,07	11,00	92,51	98,45	74,26	5.701,57	183,42	3,68	9,33	20,60	12,87	15,41	11,47	1,10
05-01-2010	11,44	14,80	8,58	88,79	99,12	61,45	4.701,07	297,45	2,70	9,17	0,13	11,43	13,32	9,61	1,10
06-01-2010	9,10	11,16	6,59	94,85	100,00	88,04	2.536,27	156,28	1,54	5,32	8,73	10,60	12,20	8,52	0,70
07-01-2010	8,20	11,57	4,56	80,24	100,00	51,38	10.493,00	330,48	2,57	8,43	8,80	10,21	11,89	7,68	1,10
08-01-2010	5,23	10,79	1,05	69,98	94,01	37,52	11.508,00	319,27	2,01	7,62	0,00	7,38	9,20	6,00	1,40
09-01-2010	4,05	11,84	-1,73	77,90	100,00	34,15	11.354,00	345,60	0,88	4,76	0,00	6,69	9,29	4,59	1,00
10-01-2010	5,28	10,15	3,18	88,02	100,00	68,02	3.054,90	120,63	3,35	9,00	9,20	6,91	8,14	5,92	1,10
11-01-2010	10,94	16,05	6,06	94,48	100,00	73,85	7.028,90	217,97	1,15	6,49	8,10	10,09	12,64	8,14	0,40
12-01-2010	12,45	15,07	10,31	97,67	100,00	87,83	1.361,20	199,00	2,42	9,25	24,70	11,61	12,66	10,62	0,40
13-01-2010	13,53	16,50	10,13	96,19	100,00	77,33	2.259,40	207,00	2,43	9,34	12,80	12,05	13,24	10,69	0,50
14-01-2010	12,73	16,05	7,59	85,52	100,00	64,24	7.162,00	272,65	1,92	7,01	0,90	12,15	13,70	10,31	0,90
15-01-2010	11,36	15,62	7,05	94,62	100,00	82,31	4.265,10	147,59	1,34	4,81	0,30	11,64	13,60	9,75	0,70
16-01-2010	14,10	18,73	11,55	96,64	100,00	84,06	3.773,30	161,96	1,34	3,98	0,60	13,23	15,48	11,84	0,50
17-01-2010	12,93	16,42	10,01	95,71	100,00	85,60	4.821,60	131,98	1,70	6,82	0,00	13,00	15,10	11,76	0,90
18-01-2010	14,24	18,61	10,15	94,16	100,00	70,29	4.332,10	170,73	1,67	6,20	0,10	13,51	15,82	11,45	0,60
19-01-2010	13,66	18,09	9,52	92,67	100,00	62,47	6.156,00	224,45	1,28	5,28	2,37	13,71	15,92	11,85	0,90
20-01-2010	12,32	18,71	7,23	88,86	100,00	55,26	7.860,90	154,97	0,88	3,36	1,88	12,82	16,54	10,47	1,00
21-01-2010	11,67	20,23	6,46	89,19	100,00	57,73	7.832,20	154,59	0,63	2,78	0,00	12,50	16,48	9,44	0,90
22-01-2010	12,09	18,09	7,67	88,92	100,00	64,50	8.252,30	91,38	1,00	3,70	0,00	13,04	16,08	10,83	1,20
23-01-2010	11,75	15,42	9,51	91,84	99,54	75,31	5.371,30	34,62	2,12	6,70	1,90	12,70	14,96	11,58	1,00
24-01-2010	12,50	17,13	9,12	88,00	99,77	64,56	10.370,00	337,17	2,06	6,50	0,10	12,94	15,36	11,58	1,20
25-01-2010	9,31	15,41	4,64	83,28	100,00	59,74	10.153,00	338,36	1,56	4,88	0,10	11,30	13,79	9,22	1,50
26-01-2010	7,86	13,39	3,74	74,97	82,71	62,18	9.166,50	35,69	4,41	12,51	0,00	9,49	11,74	7,93	1,90
27-01-2010	7,33	11,97	3,27	68,55	90,81	46,25	12.074,00	36,33	4,10	11,14	0,00	8,63	11,73	6,64	2,00
28-01-2010	8,70	15,95	3,43	68,06	88,50	40,35	13.082,00	32,02	2,93	9,22	0,00	9,03	13,81	6,73	2,00
29-01-2010	7,69	15,81	-0,74	84,82	100,00	56,80	10.849,00	302,34	1,40	8,47	0,00	8,91	13,76	5,53	1,30
30-01-2010	10,20	15,71	4,42	82,30	100,00	53,02	8.477,30	284,76	0,90	4,27	0,00	10,16	14,08	7,29	0,80
31-01-2010	10,29	15,15	5,69	87,24	100,00	65,33	6.218,40	234,99	0,56	3,73	0,00	11,17	15,56	9,01	0,80
01-02-2010	7,26	16,96	0,36	85,11	100,00	45,86	12.712,00	47,22	0,77	4,53	0,00	9,80	14,74	7,02	1,40

2 Google Earth Animation