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User-friendly Geographic Information Systems: Helpful Tools for New Crop Development

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Geographic Information Systems (GIS) emerged in the late 1980s, developed and used by geography and cartography specialists. GIS is a computer system that enables users to create, store, analyze and manage spatial data and associated attributes. In other words, it is powerful software that links features commonly found on maps, such as roads and towns, with related information traditionally not found on maps such as per capita income, or rainfall. More then just mapping software, it allows users to analyze the relationship between objects that are spatially referenced to each other. This type of analysis supports decision making. For example, GIS can be used to determine the appropriate location of a wind mill farm using parameters such as wind, land ownership, road accessibility, nearest electrical facility, soil type, and occurrence of endangered species. GIS can also be used to determine the most efficient delivery or emergency routes. In agriculture, GIS is used in precision farming systems, to maximize yields using the least amount of inputs required by the land being farmed.

When GIS was first introduced, the user community consisted of GIS specialists. The community quickly expanded to include application specialists developing products for sophisticated users. Recent advances have seen the user community expand even more broadly to include the most casual users. This has largely been due to advances in web-based GIS applications. Increasingly users with no experience with GIS can use "smart map" tools that allow them to create interactive queries, analyze spatial information and even edit data. An example of this type of application is GoogleEarth (earthgoogle.com). Users can download free software that allows them to "fly" to any location on earth. They can also find businesses or other locations and get directions. A point and click ruler allows easy determination of distances, and users can add points of interest to the web site. Web-based mapping applications benefit the casual user because they provide simplicity, accessibility, immediacy, responsiveness, and low cost (Vermes 2006).

The tight linkage between plant growth and the landscape that supports growth is widely recognized. Selecting or developing crops adapted to the targeted environment and climate is essential for sustainable production. GIS tools provide a way to understand and analyze crop performance or species occurrence within the context of the environment they are grown in. There is a wide variety of GIS software that scientists can use to support new crop development. Most users face a steep learning curve to achieve a useful level of proficiency with stand alone GIS software. It's beyond the scope of this paper to review off-the-shelf software. Rather, the purpose of this paper is to highlight web-based GIS tools that are currently available to support new crop development. We will explore tools that (1) provide users with location specific information, (2) help predict which crops grow best where, and (3) help predict where useful plant germplasm might occur. Recognizing that GIS technology is rapidly evolving, the intent of this paper is to illustrate how the web is rapidly becoming a vital resource for casual users to capitalize on GIS tools without the traditional steep learning curve. Over time, the websites discussed in this paper will become obsolete or evolve; for now, they serve to illustrate the emergence of user-friendly GIS tools, and provide a starting point for new crop developers to discover useful web-based GIS applications.

WEB-BASED SOFTWARE THAT PROVIDES LOCATION-SPECIFIC DATA

The web provides new crop developers with a wealth of data on climate, soil, crop production statistics, satellite and aerial imagery, etc. Data is available at a range of temporal and spatial scales. CROP EXPLORER (www.pecad.fas.usda.gov/cropexplorer) is a site provided by the United States Department of Agriculture, Foreign Agricultural Service, Production Estimates and Crop Assessment Division (PERCAD) (Fig. 1). The website allows users to drill down from regions of the world to individual counties, to find current and archived information on weather, soil moisture, vegetation index, satellite data, and growing season (Fig. 2). Also available are production statistics by country for crop commodities, as well as commodity intelligence reports.

AGRO-MAP (www.fao.org/landandwater/default.stm) is provided by the Foreign Agriculture Organization of the United Nations (FAO). This extensive website reports statistics on food crop production, harvested

area and yield for more then 130 countries, at a sub-national administrative level, for one or more years. The website has a simple point and click interface which allows users to interactively query the database by clicking on a map location (Fig. 3). Selecting from drop-down menus, users can select from over 67 field, fruit, and vegetable crops.

PREDICTING WHERE CROPS GROW BEST

New crop developers are interested in knowing where existing crops are grown, and were new crops can be introduced. Online resources that provide this information include CropMap which lists crops grown in the United States on a county level (Janick 2002). Bowen and Hollinger (2004) developed a powerful, user-friendly web-based application that uses a crop suitability model to characterize how suitable specific locations or coun-

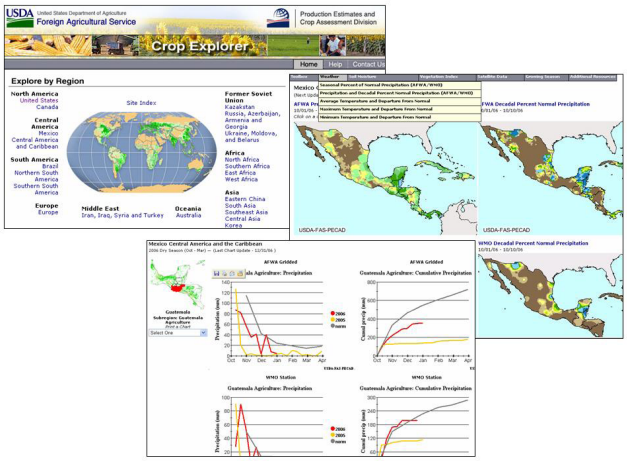

Fig. 1. The Crop Explorer (www.pecad.fas.usda.gov/cropexplorer) website allows users to explore climates around the world.

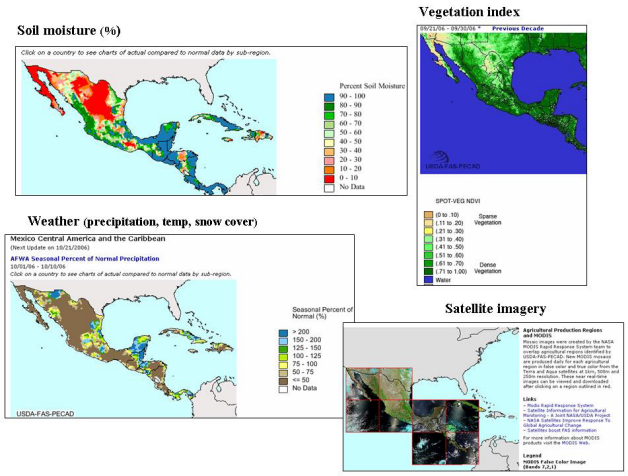

Fig. 2. Crop Explorer provides data on weather, soil moisture, vegetation index, satellite imagery, and growing season.

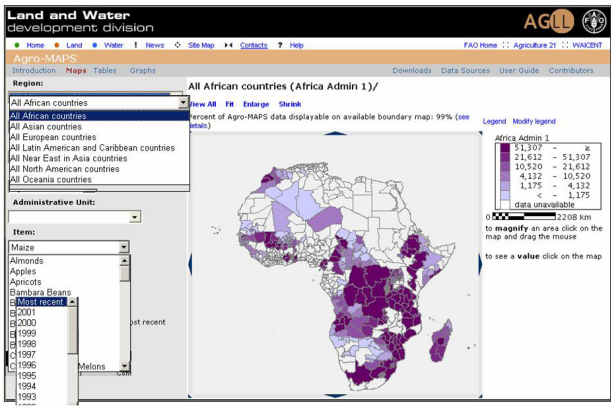

Fig. 3. AGRO-MAP (www.fao.org/landandwater/default.stm) reports statistics on food crop production, harvested area and yield for more then 130 countries, at a sub-national administrative level, for one or more years.

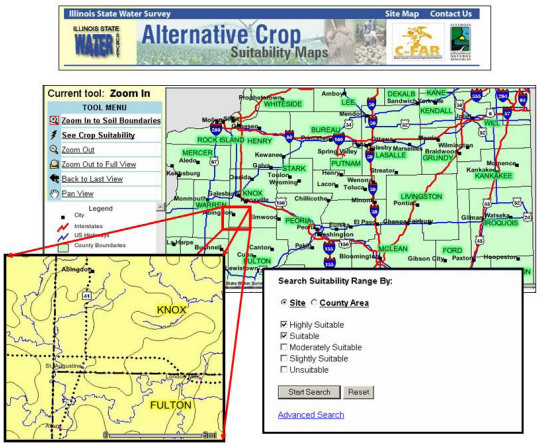

Fig. 4. The Alternative Crops Suitability Maps (www.sws.uiuc.edu/data/altcrops/) allows users to select their specific location of interest on an Illinois map, indicate an acceptable level of suitability, and receive a listing of crops that have growing requirements that match the specific location.

ties in Illinois are, for growing 414 alternative crops (www.sws.uiuc.edu/data/altcrops/). The model takes into account individual crop requirements and the geographic distribution of soil (texture, pH, drainage) and climate (temperature, precipitation, minimum winter temperature, and growing days) in the state of Illinois. Users can get information on what crops to grow using three approaches. The user can select their specific location of interest on an Illinois map, indicate an acceptable level of suitability, and receive a listing of crops have growing requirements that match the specific location (Fig. 4). Users can also get a listing of suitable crops that will grow well throughout a specific county. A third approach is to select the crop from a list, which provides the users with a detailed description of the crop requirements, as well as an overall suitability map for growing the species in the state of Illinois (Fig. 5).

The FORAGE SELECTION TOOL (www.forages.psu.edu/) and the FORAGE SPECIES SELECTION TOOL (www.forages.org), are similar programs that allow users to select the best forage species to grow in Pennsylvania and New York State, respectively. Users are able to use a click and point interface on state maps to locate the specific location their field is located. They then specify the forage management type (Hay/Silage, Pasture, Conservation), livestock being raised, soil type, drainage, and soil pH, to receive a listing of recommended and acceptable species to establish forage production for that location (Fig. 6).

PREDICTING WHERE USEFUL PLANT GERMPLASM OCCURS

New crop developers frequently look to plant germplasm collections to find the genetic variation needed to breed adapted varieties. The WEB Genetic Resources Management System (WEBGRMS) is a prototype application that allows users to select accessions from a germplasm collection which were previously collected from an environment similar to the targeted growing environment (Greene et al. 2006) (www.yukon.een.orst.edu/~greene/ms_apps/home/index.htm). This prototype application currently contains data from the USDA, ARS National Plant Germplasm System, *Medicago* and *Trifolium* collections. Using a map based interface, users can determine the Olsen Ecoregion classification (Olsen and Watts 1982), of the targeted environment (Fig. 7). The user can then obtain a list of accessions of the specified taxa that have been collected from the same Olsen Classification. Once a list of accessions have been retrieved, the user can compare monthly temperature and precipitation data based on the latitude and longitude of the germplasm collection site, with monthly temperature and precipitation data of the targeted environment to help identify the accession(s) having the most similar environments (Fig. 8).

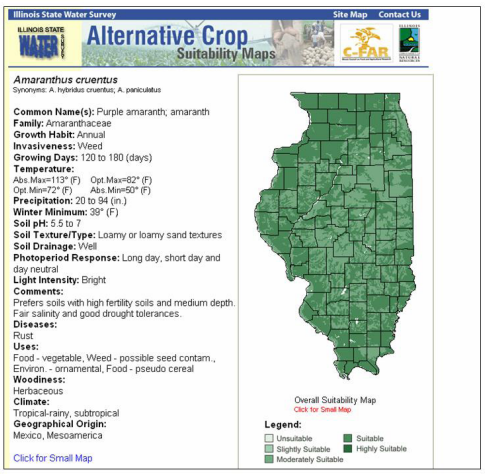

Fig. 5. An overall suitability maps is available for over 400 conventional and alternative crops

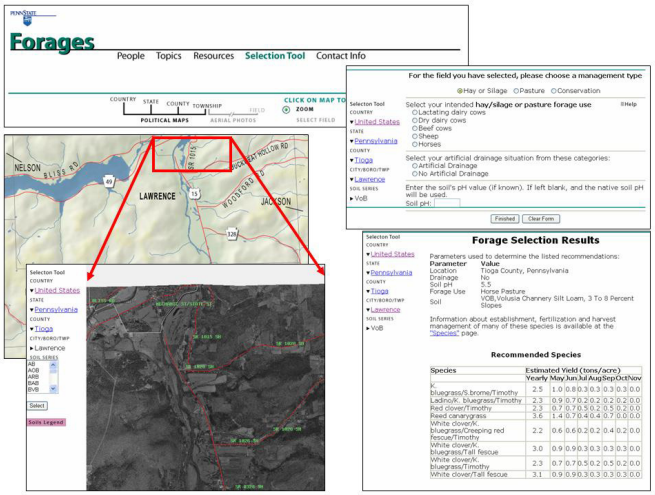

Fig. 6. With the FORAGE SELECTION TOOL (www.forages.psu.edu/), users are able to use a map interface to locate the specific location their field is located.

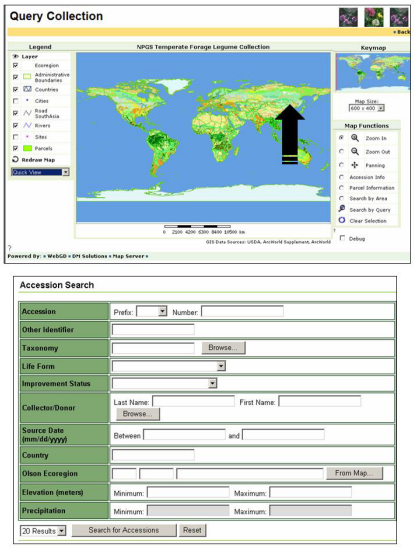

Fig. 7. The WEB Genetic Resources Management System (WEBGRMS) is a prototype application that allows users to select accessions from a germplasm collection which were previously collected from an environment similar to the targeted growing environment.

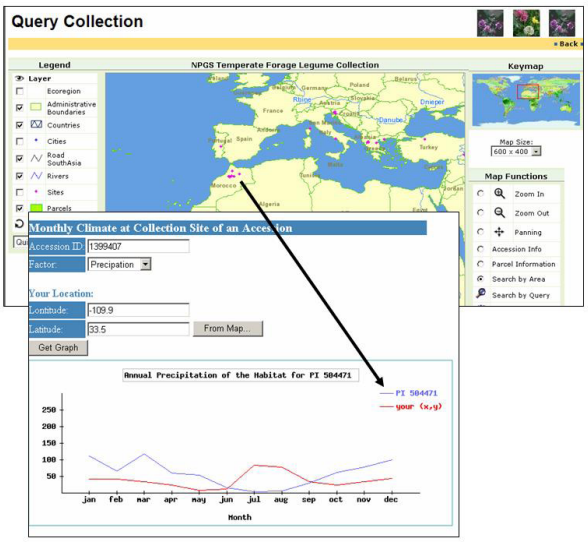

Fig. 8. Climates can then be compared between collection site of germplasm accession and the targeted environment.

CONCLUSION

This quick survey has illustrated a few user-friendly GIS tools available on line to help support new crop development. The key point is that GIS tools are becoming increasingly user-friendly, especially those applications designed to be used on the web. The future will only bring even more user-friendly GIS tools that are increasingly more sophisticated and powerful. Online access to these tools, and the ever increasing amount of online environmental data will support researchers developing new crops.

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