Developing an Agricultural, Environmental, and Natural Resources Mapping and Decision Support System (DSS) for Southeast Asia

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Abstract

A team of scientists, educators, computer, and international development specialists under the leadership of an internationally known American university with a long history of excellence in agriculture, forestry, and natural resource management is proposing to use advanced computer techniques for improved agricultural productivity, natural resource management, and environmental protection in southeast Asia. The project will develop a mapping and decision support system (DSS) that will improve agricultural productivity and natural resource management while protecting fragile ecosystems key to preserving the environment. Funding for the project will be raised by the proposing team from donor nations and international development agencies and financial institutions following a decision by governments in the region to endorse the project as needed for continued rural development and better agricultural management. The techniques proposed have been previously proven in North America and Europe and are being extended now into China. The system proposed will develop an advanced DSS based on spatial data layers of climate and soil information and a quantitative database of vegetation species tolerances. The system will permit better use, conservation, protection, and monitoring of natural resources and agricultural inputs, including soil, water, fertilizers, pesticides, etc. It will permit government officials and farmers to have a more complete view of all the factors affecting optimum choice of crop species, planting times, and rate and timing of fertilizers, irrigation, and pest control options. The complete system will take approximately five years to fully implement but more immediate benefits will be derived with the completion of climate and soil maps. The system will be delivered through the WWW and provide a "state-of-the-science" management system for agriculture equivalent to the best systems in use in the developed world.

Introduction

For many centuries, agriculture has been at the root of SE Asia's economy and society. Today, it provides food for people in the region and contributes to exports and foreign exchange earnings. Agricultural systems rely on a detailed knowledge of climate and weather for optimum production. Climate plays a major role in many decisions, such as the conservation of natural resources, land management, intensification of crop production, reduction of production costs, the improvement of agricultural products, the selection of plant species and varieties and animal breeds, and combating unfavorable influences of weather and climate on agriculture and husbandry.

While the climate of the region is known at individual points where observations are available, many agricultural areas are not represented by observations. Governments in the region should move towards a GIS-based agricultural information system to aid land managers in making important decisions to optimize production. A basic component of this i nformation system is high-quality, spatially continuous climate data that incorporates the effects of terrain, coastlines, and other important physiographic factors. Equally important for agriculture and natural resource management is detailed information on soil resources in the form of digital soil surveys. A third component is quantitative knowledge of the species and varieties of plants that are currently being used or could be used in the region.

Modern mapping technologies and information delivery systems can contribute to a more productive agriculture and sustainable development. Geographic Information Systems are being used around the world for a wide array of rural and urban land use planning and management activities including development of transportation and utility infrastructure, disaster planning (floods, earthquakes, forest fires, etc.), as well as natural resource, environmental, and agricultural management. GIS applications also are key to creating a national Decision Support System (DSS) which would include maps of an array of spatially variable data. Data are available for many areas such as population, revenue, water resources, investments, and physical situations. In agriculture and natural resources, scores of applications are possible including commodity forecasting, agricultural yield predictions, and infrastructure studies to improve agricultural yields, environmental management, impact assessment, and remediation.

The mapping and DSS system will provide detailed and accurate geographic information, improve the competitive edge of agricultural exports, and enhance sustainable development programs for local communities. Other benefits include improved ability to manage natural resources data.

Much progress has been made toward developing up-to-date geographic information with uniform accuracy in the region, but much remains to be done. Currently, geographic information is not available for many areas, since topographic, land use, and geology/geomorphology maps and other necessary geographic data have never been generated in some areas and have never been updated in other areas where initial work was done. This project will cooperate with individuals and agencies that have done initial work and build on these efforts to create agricultural applications.

Specifically, benefits include significantly improving agricultural research where spatial dimensions are relevant, collecting and providing geo-referenced data for modeling crop yields, identifying key areas of population pressure and fragile ecozones where biodiversity should be conserved, targeting more precisely where expensive pesticide and fertilizer resources should or should not be used, and providing impact assessment and economic / marketing analyses. The importance of GIS in agricultural research continues to increase as environmental management gets increasing attention on agricultural research agendas. Indeed, sustainable land use depends on intimate knowledge and this depends on detailed, accurate spatial data for climate, soils, and vegetation.

Thus, southeast Asia's agricultural system could benefit greatly from increased availability of detailed knowledge of climate and weather. Detailed, accurate information about climates, soils, and plants plays a major role in many decisions. The proposed mapping and DSS would assist with conservation of natural resources, land management, intensification of crop production, reduction of production costs, the improvement of agricultural products, the selection of plant species and varieties and animal breeds, and the combating of unfavorable influences of weather and climate on agriculture and husbandry.

Project Description

The objective of this project is to develop state-of-the-science digital maps for climates and soils, a quantitative database of crop species, and place them in the context of a web-based information and decision support system for SE Asia's agriculture, environment, and natural resource management. Similar systems have been developed or are currently under development by Oregon State University in parts of North America, Europe, and Asia. To accomplish this project and to ensure continued development following completion, a capacity building component will develop the necessary hardware, software, and networking infrastructure needed and train professionals in the use and development of the system.

The climate mapping technology to be used is known as "**Parameter-elevation Regressions on Independent Slopes Model" (PRISM**) - the world's most powerful climate mapping technology. PRISM is a knowledge-based approach to mapping climate that seeks to combine the strengths of human-expert and statistical methods (Daly and Neilson, 1992; Daly et al., 1994; 1997; 1998a; 2002, Daly and Johnson, 1999; Johnson et al., 2000). PRISM uses point data, a digital elevation model (DEM), other spatial data sets, a knowledge base, and expert interaction to generate estimates of annual, monthly and event-based climatic elements that are grids and GIS-compatible (Daly et al., 1994; 1997). The proposed work will improve and apply PRISM and ancillary technologies, to prepare detailed spatial climate data sets for the region. Further details about the PRISM climate mapping technology may be found at the following URL: http://ocs.orst.edu/prism/prism_new.html.

The soils mapping component will be based on similar work done in the USA and PRC. Resolution of soil maps will depend on data availability, likely between 1:100,000 and 1:250,000.

The database of crop species and varieties tolerances will provide quantitative values for climate and soil-based suitability for crops and other plants important to Cambodian agriculture and natural resource conservation. These will include minimum and maximum temperature, precipitation and soil water balance values, pH, salinity, alkalinity, drainage, and soil depth information. An internet map server has been developed for similar projects in the USA and PRC and is available at the following URL: http://blitzen.oce.orst.edu/arcims/adapt/
(see example below of tolerances for one grass species).

Species Adaptation Model

Region:	People's Republic of China											
Type:	Grass, Perennial, Cool-Season											
Species:	Perennial Ryegrass (*Lolium multiflorum*)											
Include?	_Y _N		_Y _N		_Y _N		_Y _N		_Y _N		_Y _N	
Suitability Level	**July Max Temp (°C)**		**Jan Min Temp (°C)**		**Annual Precip(mm)**		**Soil pH**		**Soil Drainage**		**Soil Salinity (mmhos.cm)**	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Well Adapted	22	32	-10	999	625	999	5.5	8.0	MWD	MWD	0	8
Moderately	20	34	-15	999	450	999	5.0	8.5	PD	WD	0	16
Marginally	18	36	-20	999	300	999	4	9.5	VPD	ED	0	16

The ultimate goal is to develop a web-based information and Decision Support System (DSS) that will aid the region and its land managers in improving agricultural productivity, managing natural resources, protecting from disasters, and improving the environment to ensure sustainable development.

Why Southeast Asia Needs This Project

The mapping and DSS project proposed in this document will improve the quality of life in the region by helping farmers and other system users do several things. First, the project will create a comprehensive resource of climate, soil, and crop/vegetation information that will be available on the World Wide Web. Although the Internet is not yet prevalent in rural homes in SE Asia, the Internet can be a medium to widely share information to assist rural families. In the United States, a similar project carried out by the Oregon State University Forage Information System receives thousands of contacts per month as a testament to this fact. In the USA, this resource helps farmers and agricultural advisors pick crops that are optimally suited to their specific land and the environmental conditions they face. Significantly, as conditions change from year-to-year, suitable options change. The final, integrated system will help users sort through economic data, including crop species and seed varieties, market prices, supply versus demand based on producers elsewhere, and the cost of fertilizers, fuel, and seed. The benefits from this system are many and it will constitute a valuable new tool for rural families and key decision makers. This web-accessible "library" of information will be available to government officials, scientists, policy makers, rural families (either directly or indirectly through advisors with whom they work), and other land managers.

Another important job this project will help do is to manage scarce resources. For example, if water is in shorter than usual supply because of drought, the system will be able to help users pick crops and varieties, along with planting and harvest times that may yield less but use fewer production inputs like water, fertilizer, and pesticides, thus reducing risk and resulting in a net economic and environmental gain to the farmer and the country. The system will therefore help reduce the total demand on scarce resources and help the regional economy maximize its possible returns.

A unique and compelling part of the project is that it is scaleable. Indeed, the technology and design can eventually be applicable to any place in the world as has been proven by its ongoing implementation in the USA and other countries. Elements of the SE Asia project will be used as models for adding additional geographic locations, and the benefits of this will flow into other regions of the world when the system is fully integrated over a large geographic area. This systematic approach will have the initial impact of improving the yields and standard of living of regional farmers. However, the full impact of this project will come from the development of a working implementation model that can address the needs of farmers and communities worldwide.

This project will use the models created and refined during earlier work by expanding or contracting them in terms of geography, the crops under consideration, and the sophistication level of the data and data manipulations. This adaptability will help address the manner in which individual farmers and advisors make planting decisions. Two specific visions of the project include (1) using the system to help local farmers and land managers determine which crops would be best suited for arable lands and (2) addressing topics such as nutritional and economic yield per hectare fo r scientists and government decision makers, along with methods of optimizing food production and export crops.

Project Components and Deliverables

The project consists of five parts: (1) climate spatial data layers, (2) soil spatial data layers, (3) crop/vegetation species database, (4) a web-based DSS as the delivery system, and (5) capacity building. The climate spatial data layers consist of long-term (30-year) monthly and annual maps for measured elements (precipitation, maximum, and minimum temperature) and derived elements (solar radiation, relative humidity, growing degree days, etc.). The soil spatial data layers include soil type, texture, pH, salinity, and alkalinity. The crop/vegetation database consists of quantitative tolerances of current and potential crops and other plants for the above climate and soil factors. The web-based delivery system includes elements of both information and Decision Support System technologies (information systems organize for convenient use, DSS provide assistance in the decision making process). The capacity building component will provide technical training and hardware/software and networking improvements needed by regional partners. The following table summarizes deliverables for the 5 project components for the 5 years of the project.

Project Component	**Deliverables**				
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
1. Climates	Assembling existing climate maps and information	Creating long term climatology (min. and max. temp. and precip.)	Review and revisions	Developing additional "derived" data maps	Integrating with other systems, disseminating via web system
2. Soils	Existing soil maps and information	Soil type draft map and initial review	Attribute data (texture, drainage, pH, salinity, alkalinity)	Polygons for attribute data and initial review	Integrate with other systems, review, test, revise
3. Species	Database design and draft tolerances	Database external review and revision	Draft suitability maps for selected species	National and global review and revision of initial maps	Integrate with other systems, review, test, revise
4.Delivery System	Draft design of information system	Content information system, system review and revision	Draft design of DSS component	Add content and DSS decision strategy	Announce system, conduct in-country workshops
5.Capacity	Identify overall	Purchase	Complete 1st	Complete 2nd	Develop in-

Building	needs and individuals for degree programs	equipment and initiate 1st cycle of M.S. candidates	cycle of students, initiate 2nd cycle	cycle of students	country continuing education programs

Budget

Funding will be raised by solicitation of development and research funds from potential government, development bank, and other funding sources. Project staff will take the lead in soliciting, justifying, budgeting and performing necessary reporting requirements, although individual country government support for the project is crucial in both developing support and funding for the project.

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