Title of the project:

ICT in water and Pest/Disease Management for Yield Improvement in Horticulture (Citrus)

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Project Proposal
Information Technology Research Academy -
IT Innovations for Water Resource Sustainability

Title: ICT in Water and Pest/Disease Management for Yield Improvement in Agriculture

Theme under ITRA-Water:

Improving Groundwater Levels and Quality Through Enhanced Water Use Efficiency in Agriculture

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2. PROPOSAL SUMMARY

First phase of this research aims at developing hydro-geologic frame-work model of the study area using geo-physical explorations. Aquifer composition, material properties, structural boundaries, groundwater divide, and groundwater profile will be delineated using ArcGIS environment at field scale for use with farmers, groundwater managers, and groundwater modelers of the region. Aquifer storage and yield characteristics will be estimated by analyzing pumping and recovery drawdowns in the monitoring well locations. The estimated/measured parameters will be used to develop the continuous surfaces (along with prediction accuracies) across the study region using geo-statistical techniques.

Water consumptive losses will be estimated at field scale using energy balance approach. ET flux towers will be provided to estimate the components of energy fluxes from the Citrus crops at 30 seconds interval. Data acquisition system (DAQ) will be used to accurately sense the meteorological and crop parameters, and manipulate computationally through a series of I/O sensors, controllers and GSM modules. Empirical models specific to the study area to estimate water consumptive losses by considering climate and crop parameters will be developed. Water managers and farmers of the region will be provided real time information on irrigation scheduling and frequency.

3. TECHNICAL DESCRIPTION

1. *Problem Statement*

The Vidarbha region of Maharashtra, India experience severe climatic uncertainties (uneven rainfall and severe heat) thereby giving rise to crop failure. As Agriculture being one of the major consumers of water, its efficient management is one of the main challenges over the years. In order to address the water related issues of region, this study proposes to select a few villages from Warud *taluka* (tahasil) of Amravati district for the experimental research. This study is planned to identify issues related to water-crop-disease through participatory approach.

2. *Significance*

- **Hydro-geology:** Aquifer characterization in India is available at regional scale with poor/vague representation of detailed information. In order to develop reliable 'soil-water-crop' models that can be used by water managers and water users of a region, a more detailed representation of aquifer composition, material characteristics, groundwater divide, structural boundaries at field scale is needed.
- **Groundwater**: The groundwater status is "Over Exploited" in the target location which means that groundwater development/usage is more than 100% of the recharge, and the water table during either Post or Pre monsoon interval or both shows declining trend. There is a need for a system to enable measurement and monitoring of groundwater level to aid in managing the water efficiently.
- **Irrigation:** Farmers do not follow the right irrigation practices due to unavailability of right information on stagewise crop water requirements. There is a need to optimize and control irrigation based on research findings related to crop models.
- **Disease:** Orange is a major crop of the region, every year significant yield loss is reported due to a *Phytophthora* root rot disease locally called "*Dinkya*". It has been seen from literature that improper/excessive surface irrigation resulting in water logging has a strong correlation with this disease. Hence there is a need for research work to find measures to prevent/predict the onset of the disease so that timely control measures can be taken by the farmers for better yields.

3. *Challenges Posed by the Problem*

- Groundwater: Continuous measurement of groundwater level is a time consuming expensive and cumbersome method. There is need for quick and real time system for measurement of groundwater draft.
- Irrigation: Real time location specific field data is unavailable due to high variability in meteorological parameters in semi arid regions. To optimize the irrigation based on crop models in this scenario is a challenging problem.
- Disease: It has been found that region specific crop disease model do not exist for Citrus crops. There is a need for development of crop disease prediction models based on agro-meteorology and real time surveillance data.

4. *State of the Art*

- Hydro-geology: Most of the regions of India are lacking in proper management of groundwater resources due to poor representation of aquifer characteristics and water budget parameters into groundwater models. There is an immediate need to address this issue by carrying out field scale experiments.
- Groundwater: GRACE Satellite data can provide real time groundwater depletion level information. However it has coarse resolution and is expensive. Data from Central Groundwater Board (CGWB) by physical measurement is subject to error. A system that results in low cost real time data is needed.
- Irrigation: Very few farmers are using automatic controlled micro irrigation systems and are expensive. There is a requirement for a low cost real time system. Further, the existing crop models need to be calibrated and validated with actual data from fields.
- Citrus Disease: The prior research shows significant impact of increased soil moisture on the *Phytophthora* root rot disease of Citrus. However, in literature, the disease model for the selected region is not available. The control of water supply to mitigate the diseases in Citrus is hence a difficult problem. According to Tripathy et al. (2011), data mining techniques can be used to find out the correlation of multiple weather parameters as well as soil moisture with respect to crop diseases. More details of the

literature along with methodology to address this problem is presented in the section 3 under the subsection 'Details of Proposed Approach and Implementation'.

5. *Overview of Proposed Approach*

In this proposal, an attempt will be made to approach water sustainability problem by providing technological, economical and behavioral solutions to the 'most critical water related problems in agriculture. Due to continual depletion in groundwater levels, availability of water for irrigation and household usage has become a challenge. This brings out to one of the important needs to develop information on various aspects of water resources and its related/dependable sectors such as agriculture for better decision making. Various ICTs, including spatial (RS/GIS/GPS), proximal (sensor network) and crowd-source systems becomes handy for information gathering, dissemination and monitoring of various biophysical phenomena and to work in integrated environment. This study also involves in the development of algorithms to compute the demand/supply of water to mitigate the water scarcity, irrigation planning and crop diseases. Furthermore, modeling and integrating different systems to solve various issues in Citrus cultivation with focus on water sustainability would be carried out.

The proposed architecture to integrate different systems through multi-modal communication platforms is depicted in Figure 1. The Datamatrix system (Datamatrix Infotech Pvt. Ltd) will provide groundwater parameters measurement by deploying energy meters on the pumps in the selected region. This will help in energy conservation and also to improve the water use efficiency. The Agrisens and FieldServer architecture will provide wireless sensor networks to monitor farm related parameters with high spatio-temporal resolution. These parameters will assist in development of region specific crop and disease models which in-turn will help in optimizing the irrigation. The mKRISHI™ platform will provide mobile phone based ICT framework for query reasoning and for information dissemination. The participatory sensing framework of mKRISHI™ will assist in detection of the disease symptoms for developing disease forecasting models. The data collected by different systems would be brought in the standard format in the proposed Interoperable Service Oriented Architecture. This integrated approach would provide a low cost and efficient solution for water related issues in agriculture. The detailed description of these systems and their utility in different problem categories are mentioned in subsection 'Details of Proposed Approach and Implementation'.

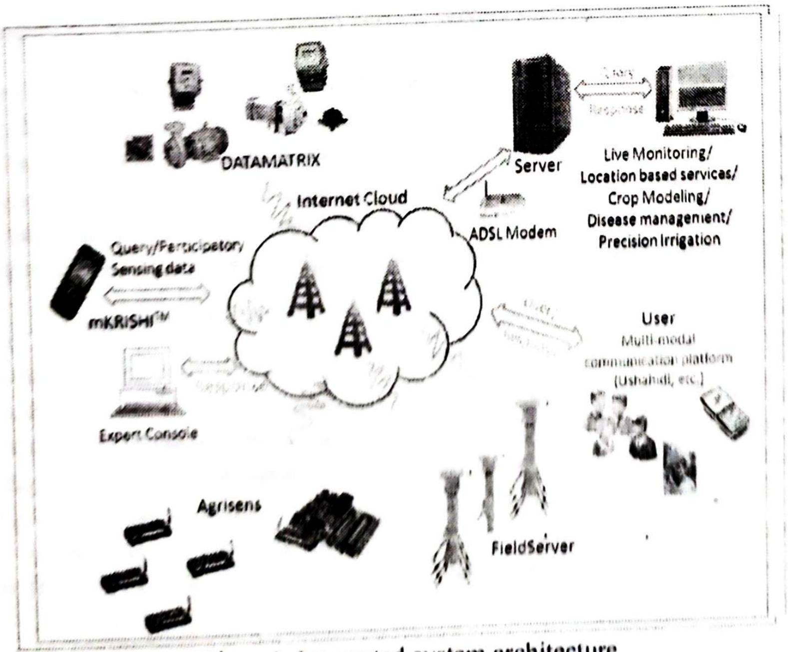

Figure 1. Integrated system architecture

6. *Metrics*

Following are the indicators for measuring the technical impact expected from the proposed research and development.

Groundwater

- No. of zones identified as over exploited
- Reduction in percentage of inefficient pumps
- No. of zones where groundwater recharge techniques can be implemented
- Percent increase in sub-surface water levels
- Water quality awareness and improvement

Irrigation

- Percent savings in implementation of automatic micro irrigation system
- Percent increase in efficiency of crop water model
- Percent increase in efficiency of water usage for irrigation
- Percent increase in crop yield
- Percent increase in irrigated area
- Percent increase in crop production area

Disease

- Percent increase in efficiency of disease forecast model
- Percent reduction in pesticide usage (Eco-friendly approach)
- Percent reduction in losses due to diseases
- Development of groundwater models

7. *Details of Proposed Approach and Implementation*

The detailed technical description of the proposed objectives is presented in following part of this section.

7.1 Improving Groundwater Levels and Quality through Enhanced Water Use Efficiency in Agriculture

In the Indian context, under the scarcity of surface water resources, groundwater is a key element in water resources, and its demand/supply play an important role in various sectors. Groundwater depletion is the terminology used for long-term water-level deterioration due to excessive groundwater pumping (USGS, 2003). Some of the prevalent problems are over exploitation of groundwater, increase in energy/pumpage cost, land subsidized, reduction in groundwater movement in aquifer resulting in decline in surface water availability and deterioration of groundwater quality (Alley et al., 1999). Therefore, measurement, monitoring and management of water levels is essential to avoid over exploitation of groundwater. Further, monitoring of groundwater quality is also an important aspect for its utility decisions in various sectors such as agriculture, domestic and industry.

The project proposes to investigate and implement the energy and water flow measurement systems in order to control the water supply to various users. This could enable the villages to set up a self-regulating regime for water management. The proposed ICT system would have provision to generate reports for monitoring water usage and energy consumption for a farming group. It can also provide groundwater level at each point of withdrawal and facilitate energy and water audits. Based on crop water requirement and usage parameters, alerts could be sent to the farmers. Also there could be provision to automatically control the irrigation pumps.

Research Challenges

The key objective of this research is to '*improve water use efficiency*' in rural areas with the aid of advanced ICT, sensing and control technologies. The project proposes to investigate and implement the energy and water flow measurement systems in order to control the water supply to various users. This could enable the villages to set up a self-regulating regime for water management. The proposed ICT system would have provision to generate reports for monitoring water usage and energy consumption for a farming group. It can also provide groundwater level at each point of withdrawal and facilitate Energy and Water Audits. Based on crop water requirement and usage parameters, alerts could be sent to the farmers. Also there could be provision to automatically control the irrigation pumps.

In addition to improve the water use efficiency, '*water quality*' is one of the key issues in semi-arid tropics, and particularly in Nagpur-Amravati region. Fluoride content in the region is >1.5 mg/l, Iron is >1.0 mg/l and Nitrate is > 45 mg/l (Source: http://www.cgwb.gov.in/). Here we also aim to develop technologies which can provide instantaneous information about groundwater quality to the user community by installing water quality sensors for measuring and monitoring various parameters such as Electric conductivity, Salinity, Temperature, pH, Dissolved Oxygen, and Total Soluble Solids (TSS), etc.

Methodology

For measurement of groundwater depth, we plan to use the techniques such as: Remote Sensing and GIS approach [Gravity Recovery and Climate Experiment (GRACE) satellite mission data] (Tiwari et al., 2009), data from Central Groundwater Board of India (Source: http://cgwb.gov.in) and water flow measurement systems using energy meters (Datamatrix Infotech Pvt. Ltd).

Surface electrical resistivity techniques with Schlumberger and Wenner's configuration will be developed to characterize sub-surface information for the study area. Vertical profile curves will be developed and then adjusted with the theoretical Vertical Electrical Sounding (VES) curves by considering 2 and 3 layered strata. Horizontal profile curves will be developed qualitatively with the aid of local geologic information. Basic hydro-geologic maps delineating the water table profile, aquifer composition and depths, presence of surface faults and cavities, etc. will be developed in ArcGIS environment for the entire study area.

Aquifer pumping and recovery tests will be conducted at the location of major pumping wells by monitoring the drawdowns in the observation wells after achieving steady state condition. Storage and pumping parameters including aquifer storage coefficient (S), hydraulic conductivity (k), Transmissivity (T), etc. will be estimated from the results of pumping analysis. Soil parameters will be estimated in the laboratory/field for porosity, suction, water content, moisture holding capacity, etc. Spatial distribution of all parameters for each GP will be developed using geo-statistical techniques.

Point or distributed parameters (includes hydro-geologic, hydrologic, and pumping parameters) that were estimated/measured for the study area will be analyzed for trend and outliers. Various theoretical semi-variograms will be fitted for the observed data, and best kriging technique to be used for each parameter will be decided based on cross-validation statistics. Contour maps, continuous surfaces, and estimation variance surfaces for each parameter across the study area will be developed in ArcGIS for ready use by farmers, water managers in effectively managing the groundwater resources of the region.

Water consumptive losses across the study area will be estimated using energy balance approach using network of ET flux towers. Data acquisition sensors that were connected to the energy measurements will transfer the data to the host computer for analysis. Non-consumptive losses will be estimated using water budget. Consumptive losses will also be estimated at field scale using SEBAL algorithms, and validated with direct measurements. Empirical models specific to the region in terms of Citrus crop growth and climate parameters will be developed and used for estimating irrigation frequency and scheduling.

Remote sensing and GIS are useful tools for assessment and monitoring of groundwater resources. Satellite data facilitates information of various hydro-geomorphologic components such as surface geological/structural features, lineaments, soils slope, land use/cover, etc. The hydro-geomorphologic components derived from satellite data could be combined with other ancillary and ground truth information in GIS environment for allocation and design of areas suitable for artificial recharge.

Integrated Water Management system (Datamatrix Infotech Pvt. Ltd.) provides virtual metering of several operating parameters of a remote water pumping system by measuring energy consumed by the individual pumps. The system comprises of one energy meter for each pump with wireless data communication to a central server. The server can process and interpret the energy data to obtain various operating parameters like water output, energy consumption, and groundwater levels. This data will be used to analyze and improve energy-water efficiency.

For the purpose of sensitivity analysis and optimization, the groundwater system balance component obtained from the remote sensing and energy flow meter approaches would be compared with that of CGWB primary data.

The proposed methodology for groundwater resources planning and management is shown in Figure 2. Here, surface energy balance algorithms (SEBAL) will be used for estimating the spatio-temporal variability of crop water requirement of Citrus orchids which in turn lead to assess the irrigation requirements and irrigation water return flow. We further propose to balance the groundwater system by identifying the over exploited and critical zones along with implementing groundwater recharge techniques. The energy measurements obtained from deploying the energy meters on the pumps will lead to development of reduced pumpage cost strategies.

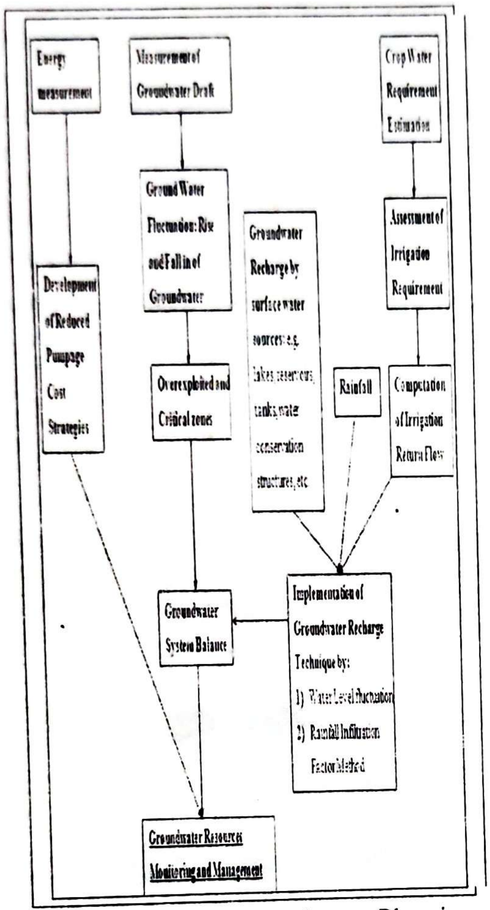

Figure 2. Proposed Flowchart for Groundwater Planning and Management

Scope of the Research

In this project, the following objectives are proposed to be achieved for the study area

- Development of water table trends
- Estimation of net available groundwater and its efficient allocation for agricultural, industrial and domestic purposes
- Development of scenarios for future groundwater availability
- Socio-economic evaluation of groundwater and energy usage

7.2 Smart Sensor and Automated Control Based Drip Irrigation System

The decision of irrigation for any crop depends on the crop type, its phenological stage and weather conditions. Optimized irrigation will lead to efficient utilization of available groundwater and improve the crop yield. An attempt will be made to use the sensor and actuator technologies in the Citrus orchards to optimize and automate the drip irrigation systems. One propeller eddy co-variance (OPEC) flux towers along with soil heat flux plates and net radiometers will be installed in the study area to estimate daily evapotranspiration (ET) flux directly. Data acquisition techniques will be used to transfer the energy fluxes at 30 minute interval to the host server and thus to manipulate for missing data. Empirical equations applied for Citrus crops (Allen et al., 1989) will then be modified and applied to compute the irrigation scheduling for the area under study.

For Peach orchards, Casadesús et al. (2012) have developed two alternative methods to estimate the crop water requirements that are based on evapotranspiration and based on variations of solar radiations intercepted by the canopy. The sensors used for this project were energy flux meters, soil moisture probe and dendrometers to measure the growth of the tree trunk. Based on these two approaches the drip irrigation scheduling was obtained which in turn was used in automation of the drip irrigation system.

A closed loop irrigation system consisting of smart sensor array was used to determine timing and amount for real-time site-specific irrigation application for cotton crop (Vellidis et al., 2007). The effect of drip irrigation scheduling on crop yield and quality was studied in controlled environment (Li et al., 2012).

Objectives

- Integrate the empirical crop-water models with sensor systems and design optimum irrigation schedule for citrus crop
- Optimize and evaluate operating policies for automatic drip irrigation systems using Wireless Sensor Networks, control equipments and ICT systems

Methodology

This would involve deployment of WSN with energy fluxes, soil moisture, leaf wetness, dendrometer, plant canopy temperature and canopy humidity sensors. Here we envisage to optimize drip irrigation schedules through both conventional modeling and sensor data analysis (Figure 3).

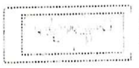

Figure 3. Schematic block diagram

Using these optimum irrigation decisions, sensors and actuators based automatic micro irrigation system, preferably drip irrigation system, would be designed and developed (Figure 4). Efforts will be made to use SEBAL method to spatially understand the crop water requirement of an area, and will be validated with hyperspectral signatures, conventional and sensors data.

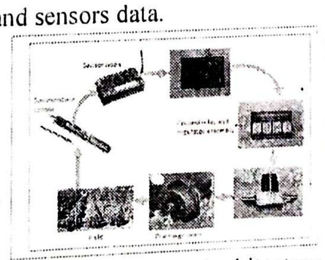

Figure 4. System Architecture

(Adapted and modified from Neelamegam et al., 2007)

7.3 Plant Diseases and Yield Improvement

In Maharashtra, particularly Nagpur region, is a leading citrus crop cultivating state. However, every year a huge loss to citrus production occurs due to damage caused by different biotic agencies such as insect pests, diseases caused by fungi, bacteria, virus, mycoplasma, and of course, some special problems like alternate bearing, fruit drop, citrus decline, granulation, etc. One of the prevalent diseases in citrus is Gummosis, which is caused by *Phytophthora* species (Grimm and Timmer, 1981; Klotz, 1978). The improper surface irrigation practices resulting in water logging may cause the Gummosis in Citrus (Chandy, 2012). Irrigation strategies based on allowable water deficit have a significant impact on the yield of Citrus (Moreshet, 1983). Fletcher et al. (2001) have used various remote sensing techniques such as arial color-infrared (CIR) digital imagery and ground spectroradiometry for detection of *Phytophthora* infected citrus trees.

Data mining techniques were used to turn the sensory (Agrisens) data into useful information/knowledge/relations/trends and correlation of crop-weather-pest/disease continuum. These dynamics obtained from the data mining techniques and trained through mathematical models were validated with corresponding surveillance data which lead to develop a real to near real-time decision support system for pest/disease predictions for Groundnut (*Arachis hypogaea*) crop (Tripathy et al., 2011). Similar approach will be adapted for the citrus crop-disease relationship modeling (Figure 5).

TCSs' Sensor Network and Human Participatory based Plant Disease Forecasting System is an innovative platform for minimizing spray of pesticides while keeping the disease risk to its minimum (Pande et al. 2009a; Jagyasi 2010, Pande et al. 2009b, Pande and Jagyasi, 2011). The proposed Plant Disease Forecast System combines existing sensor based mathematical plant disease forecasting models and mobile phone based human participative diagnosis. The mathematical models based on sensor parameters help to detect the conducive climate for the inoculation of the disease. While the actual observation of symptoms help to detect the actual disease attack due to the presence of the pathogen. This aids in determining the timely and appropriate doses of pesticide.

The major Research objectives in Plant Disease control and Yield improvements are

- Modeling and optimization of irrigation strategies for mitigation of major diseases in Citrus. The study will formulate agro-meteorology based risk prediction models for *Phytophthora* infection in Citrus.
- Study and quantification of Spatio-Temporal Plant Disease epidemiology using proximal systems such as Wireless Sensor Networks, and spatial systems such as hyper-spectral Remote Sensing and GIS techniques.

Methodology

For Plant Disease modeling, we propose to deploy wireless sensor network to monitor the agro-meteorological parameters (temperature, humidity, soil moisture, leaf wetness, etc.) from the citrus farms. The Agrisens and FieldServer systems integrated with mKRISHI^{TM}/Ushahidi will be deployed for real time monitoring, modeling, agro-advisory and information dissemination. Further, mobile phone based human participatory sensing would enable collection of the symptoms to obtain the crop disease severity from the remote farms. The design and development of location specific crop disease models would be based on stochastic approaches as shown in Figure 5. In addition to this, we envisage to use the hyper-spectral remote sensing data for detection of the crop diseases. The information dissemination shall be carried out through multiple channels such as mobile phone applications, web consoles, etc. including crowd source platform such as Ushahidi.

Figure 5. Processing flow for pest disease dynamics (Tripathy et al., 2011)

7.4 Integrated Model and Interoperable services

The data collected by sensor systems (Agrisens/FieldServer, mKRISHI^{TM}, DATAMATRIX, etc.) are in their own indigenous formats thereby giving rise to syntactic and semantic heterogeneity (Honda et. al., 2009; mKRISHI^{TM}. 2009; Sudharsan et al., 2012; Lee et. al., 2010). Interoperability between these systems can facilitate the decision support for agricultural resources (water, fertilizer, etc.) management of region. Hence there is a need for service oriented architecture which can avail communication between different systems to a common platform.

The major objectives include:

- Standardize sensor data from multiple platforms/ sensor nodes for various stakeholders
- Improvement of integrated system as compared to independent systems
- Real Time Decision Support System for water use, disease management and yield improvement

Interoperable Service Oriented Architecture for distributed sensor network in Citrus

The Sensor Web Enablement (SWE) architecture has been developed by Open Geospatial Consortium (OGC) to standardize the communication between the service-provider and service-user (Botts et. al., 2006).

The Sensor Model Language (Sensor ML) Framework can provide system description, process model, process chain, connections and system physical layout (Figure 6). This facilitates to sensor data discovery by identifying the exact lineage of collected data (Botts et. al., 2007).

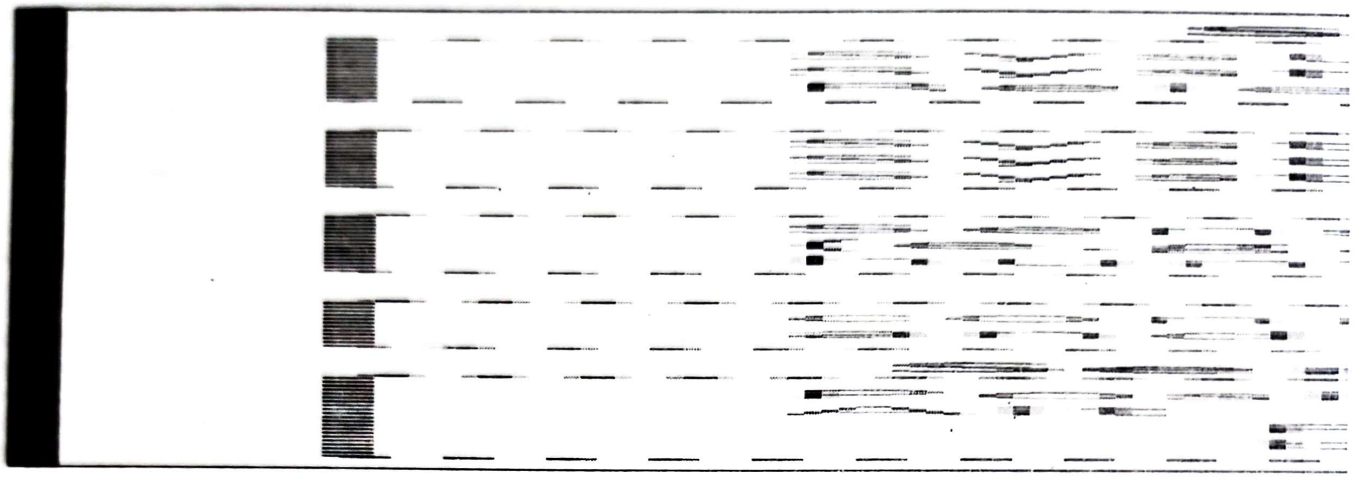

Figure 6. Sensor System Framework

Sensor Observation Service (SOS): It is a part of OGC Sensor Web Enablement. It acts as a medium for the exchange of data between repository of data and the client. It enables the client to request, filter, retrieve observations and sensor system information from the database. In addition to the sensor data, this web service can also host the SensorML documents of the sensors (Arthur and Priest 2007).

In the present study data from different sensing systems will be collected, verified (checked for any-discontinuity, outliers, errors, etc.) and stored in standard format of SOS database. The data will be processed through both pre-existing and new set of crop-water-disease models. Outcome of modeling service will be compared/validated by researchers (IITB, TCS, NRCC, etc.) in real time. The SOS client will be developed to support visualization of data through multi-modal communication platform (Durbha et. al., 2010). Schematic of ICT enabled services for water, crop disease management and yield improvement in agriculture is presented in Figure 7.

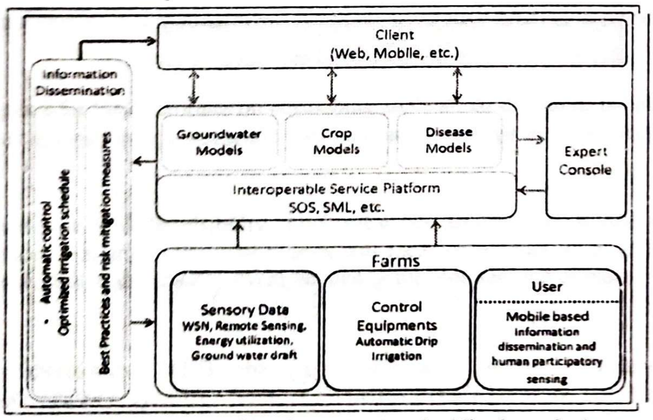

Figure 7. Schematic of ICT enabled services for water sustainablity in agriculture

7.5 Deliverables

This proposal aims for development and management of land and water resources through Geo-ICT based approaches. The expected outcomes are:

1. Creation of digital hydro-geologic framework model of the study area
2. Development of groundwater conservation strategies
3. Sensor based automation in micro irrigation system
4. Pest disease forecast models for yield improvement

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5. Multi-modal information collection and dissemination platform
6. Location based services through Geo-ICT
7. Real time Decision Support System
8. Local capacity building of faculty, students, users and other stakeholders

4. CURRICULUM (At most 2 pages)

The project would put into practice a Public-Private-Partnership (PPP) approach involving various interdisciplinary teams including farmer groups, academicians, researchers, scientists, private firms, etc.

Courses
At CSRE IIT Bombay, a new course on *'Sensor Network and its application in Natural Resources'* could be added in the curriculum. Pre-existing course entitled *'Advances in Geospatial Standards, Interoperability and Knowledge Discovery'* will be enriched with examples and findings from this research program. At Civil Engineering Department, IIT Hyderabad, two graduate level courses titled *'Applied Hydro-Geology'* and *'Hydrologic Systems Analysis'* will be enriched based on the research findings.

Capacity building programs
During the three years of this project, various trainings, workshops, seminars and user interaction programs for capacity building will be carried out with the help of domain specific Faculty, Scientists and industry experts. The potential participants of this program would be M. Tech., Ph. D. Students, Researchers and participating field level stake holders.

Seminars for Academicians
- Wireless Sensor Network (WSN) Technology and its Application in Agriculture
- Agro-meteorology based Citrus Pest and Disease Modeling
- Geo-ICT and WSN for Agro/Rural Informatics

Seminars for Target User base
- Citrus Pest and Diseases: Impact and Mitigation
- Hydro-geologic characterization and Interpretation
- Irrigation Planning and Management in Citrus Crops
- Groundwater Planning and Management: Judicious Utilization-Sharing responsibility

Training/ Workshops
- Training programs for local institutes on developing applications on mobile phone
- Awareness workshops for local academic institutes on applications of IT in water-crop-disease management

The above programs will provide wider visibility to the researchers to solve agricultural sustainability problems in rural areas. The usability training to the rural masses will focus on optimal usage of the water resources for irrigation, consumption as well as on timely preventive management of pest and diseases.

New laboratories
- The existing laboratories at IIT Bombay (Agro-Informatics Lab) and TCS (Innovation Lab) would be upgraded with Sensory Systems - Sensors (Wireless Sensor Network kit), Network gateways, mini PCs, FieldServers and integrated database servers, Staging and Production Servers, respectively.
- A new research laboratory at IIT Hyderabad titled "Hydro-Geo-Informatics' Lab will be developed to estimate, analyze, and simulate sub surface characteristics using geo-physical exploration techniques.
- The Amravati Engineering College Lab (Mentee Institute) would be upgraded with high end facilities related to ICT and agriculture such as high precision test and measuring instruments, SMD base station, fuzzy logic controllers, sensors, circuit components, actuators, annunciators, etc.
- The Shivaji Science College of Horticulture (Mentee Institute) would be upgraded with equipment for soil testing, pathogen study, etc.

New databases
The research program would result in creation of Knowledge Management Repository in the form of following interoperable databases:

- Hydro-geological information, Crop and climate specific water use efficiency database
- Agro-meteorological, surveillance database
- Groundwater status/profile database
- Crop specific query database (through human participatory approach)

New computer solutions

- Simulation Models for improving the performance and efficiency of the pumps to be implemented with the help of Datamatrix systems.
- Also, simulation models would be developed for crop-water-disease prediction.

New MS/PhD students

The common platform with new interdisciplinary teams (Computer Science Engineering, Electronics and telecommunication, Agriculture, Horticulture, Entomology and Civil Engineering) and the varied curriculum would attract PhD and Masters Students to work on research problems.

Effectiveness of Curriculum would be measured by (a) The number of participants (students, researchers, practitioners, etc.) and (b) The number of distinct citations and users of developed solutions (simulation models, prediction algorithms, laboratories, etc.).

5. SOCIETAL SENSITIVITY DEVELOPMENT (At most 2 pages)

The existing approaches such as mKRISHI™ – Mobile phone based agro-advisory services, plant disease forecasting system, Agrisens (WSN for precision agriculture), GeoSense (short/wi-fi range WSN for precision irrigation, energy fluxes, crop yield modelling, pest modelling), integrated energy meter based water management systems aim to minimize the cost of cultivation in order to increase the farming efficiency. The mKRISHI™ framework provides advice to the farmers to take the right decisions at right time. The plant disease forecasting system aims at minimizing the spray of pesticides resulting in improvement in the quality of produce as well as quality of soil. This results in implication of an environment-friendly method to control the farming losses due to plant diseases. The Agrisens and GeoSense (http://www.csre.iitb.ac.in/geosense/index.html) provides deployment of wireless sensor networks and field servers to monitor the farm parameter and to automatically control the irrigation pumps, thereby resulting in precision and controlled agricultural practices. These precision agriculture approaches help to optimize the farming practices in order to improve the farmer's income, conserve the environment leading to an enhanced the quality of life for the rural folks. In the current proposal, integrating the information and knowledge from these existing systems to solve the water sustainability problems in Citrus (Orange) cultivation in the Nagpur region is envisaged. Through this project, an attempt will be made to preserve the traditional art and culture of orange cultivation in the Nagpur region of India by using advanced Sensors, Mobile Computing and ICT technologies.

The proposed research project is based on soil-crop-water utilization, having four focus areas such as groundwater conservation in rural areas, smart sensor and automated control based micro irrigation system, plant diseases study for yield improvement and integrated model with interoperable services for water sustainability. The project proposes to investigate and implement the energy/water flow measurement systems in order to create awareness among the root level users for its judicious utilization. This could even enable the villages to set up a self-regulating regime for water management. The implementation of smart sensor and automated control based micro irrigation system will help in conservation of water and improvement of the crop yield. Plant diseases study will aim to reduce the use of pesticides and improve the crop yield by reducing losses due to plant diseases. Integrated model and interoperable services along with mobile phone based information dissemination will enhance the outreach to a larger part of society.

In addition to the technological interventions, resource based Systems Dynamics (SD) approach will involve the researchers to identify the causal relations between natural resources and energy utilization of the region. This will be further strengthened by incorporating social science research methods e.g. Participatory Rural Appraisal (PRA) or Rapid Rural Appraisal (RRA). This has components of public discussions/meetings and activities such as social mapping, problem ranking, seasonality, etc. which would facilitate for a long term and healthy relationship with the farming community.

In the curriculum section, it is proposed to undertake various inter-disciplinary courses and course modules such as 'Sensor Networks and its Application for Rural Informatics', which shall include lectures on technologies for societal problems. In these courses, it is aimed to provide fieldwork based assignments to students so as to train the farmers on farming practices for water conservations. Further, the project also plans to impart trainings and workshops for the rural masses for creating social awareness and build their confidence to approach the social issues.

Metrics: The metrics used to quantify the successful implementation of the proposed initiatives for social sensitivity development are:

- Number of courses on societal problems - 1 to 2
- Number of successful trainings on water conservation for the rural masses - 3 to 5
- Number of usability trainings to the farms to use the mobile phone application conveniently - 3 to 4
- Positive results indicating farmers showing enthusiasm in utilizing the proposed systems. [These results could be obtained from Participatory Rural Appraisal (PRA) or Rapid Rural Appraisal (RRA)]
- Results on significant reduction in pesticide usage leading to social and environmental effect
- Results on reduction in groundwater overexploitation by the rural people because of awareness due to training programs
- Interoperable database for day to day decision making in rural systems

6. OUTREACH AND ENTREPRENEURSHIP PLAN (At most 2 pages)

There would be meetings with farmers and orange growers association to identify experimental fields for installation and maintenance of sensors for the pilot. This would set up a mechanism for efficient management of water and crop disease. The capacity building workshops would be held in collaboration with NRCC and other ICAR institutes to share the crop-disease-water research experiences. The agro-meteorology based crop-water-soil-disease models would provide additional insights to the available resources.

The low cost automatic micro irrigation system can be scaled-up, thereby improving the net cultivated area. Local entrepreneurs can be created who would perform the handholding and procurement activities.

Interoperable datasets and multi-modal communication platforms generated in this research would be useful for other research domains of science and technology like environmental, health, horticulture, etc. The developed models and integrated datasets will empower the govt. departments for policy decisions.

There would be collaboration with Datamatrix to study energy based water utilization pattern of the region. The data analysis from Datamatrix system would provide insight on water consumption and efficient usage methods for a fair distribution. This could be integrated with multi-modal communication/crowd source platforms (e.g. mKRISHI™ and Ushahidi) platform for enhancement and outreach to the rural masses. The alerts on over exploitation of water and energy, crop diseases, agro-advisory and other information dissemination through mobile phone application could facilitate a large number of farmers for taking appropriate decisions.

Also, a "Recharge" Plan could be developed with the help of Non Government Organizations (NGO) and/or Government programs for the "Over Exploited" water zones. Participatory Rural Appraisal (PRA) program could be conducted to build capacities of the villagers. The villagers could appoint an Engineer/Consultant for Water Conservation plan of the village. The water pump efficiency dashboard from Datamatrix would generate possible opportunities for water pump repair/replace services.

After the successful completion of research implementation, the project would be deployed on a larger scale with the help of local people (local entrepreneurs) participation. In an outreach plan, the local scouts, technicians and organizations can assist in activities such as data collection, system deployment and maintenance, farmers registration and hand-holding, marketing and supervision. The entrepreneurs can generate the revenues for providing these services to scale-up the proposed systems. Further, the self-sustainable models would emerge with these entrepreneurs with the experience and the knowledge gained from these projects, leading to significant economic benefits.

The mentee institutes would be enriched in terms knowledge, research facilities, visibility and support. The plan for involvement of new mentee institutes towards the end of 2^{nd} year of the programme will enable similar strengthening of the institutes.

The outcomes from the research will be internationally published in journals/conference proceedings. This will give visibility of the research work to students, researchers, scientists, etc. across the globe. The feedback obtained could help in further refinement/improvement in the research programs.

Metrics: Effectiveness of outreach

- Number of pilot studies and recipients
- Comparative analysis of past and present scenario of water availability and extent of crop disease mitigation
- Number of publications, capacity building (seminars, workshops, training programs, etc.)
- Number of participants from mentee institutes
- Average increase in annual income of Orange Growers
- Number of Entrepreneurs generated