CLIMATE CHANGE SCENARIOS WITH WIRELESS SENSOR NETWORK & GEO-ICT— A PRELIMINARY OBSERVATION

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ABSTRACT:

A preliminary study was carried out under shed-net condition to observe climate change scenarios on tomato crop. Wireless Sensor Network (WSN) technology was used in the studies to monitor climate parameters (temperature, humidity and CO_2 concentration) continuously under micro-climatic conditions. WSN Devices used for the studies were: FieldServer and Agrisens. DSSAT (Decision support for Agrotechnology Transfer) simulation software tool was used to determine scenarios of crop yield under different CO_2 and Temperature conditions. In addition, coping strategies were also studied to combat the change scenarios. OpenSource/Free Geographical Information and Communication Techniques (Geo-ICT) tool was used for sensor web enablement and for dissemination to the rural community.

1. BACKGROUND

Agriculture is the mainstay of the Indian economy, as it constitutes the backbone of the rural livelihood security system. Climate is one of the important primary factors for agriculture production. The impact of climate change has a bearing on crop yields (both positively and negatively); choice of crops that can be grown in certain areas; agricultural inputs such as water for irrigation; amount of solar radiation that affects plant growth as well as the prevalence of pests.

Real time monitoring of micro climatic and growth parameters of crop are one of the important requirements to study the impact of climate change in a specific agricultural land o be collected in the field. The climate parameters, and in particular crop growth environmental factor CO_2 concentrations usually are obtained from the nearly weather / experimental stations, which are sparse and difficult to model at micro climatic level.

With the advent of low cost wireless sensor network (WSN) technology, one can obtain micro climatic parameters from a specific field in real time, which will improve the agricultural decision making and apply coping strategies to combat the threats from climate changes. FieldServer (FS) (FieldServer, 2004) and Agrisens (SPANN Lab, 2009) are the two distributed sensing devises extensively used in rural systems for various agricultural aspects.

Decision support system tools such as DSSAT (Decision support for Agrotechnology Transfer) integrates the effects soil, crop phenotype, weather and management databases that simulate crop management strategies for different crops at any location in the world (ICASA, 2009). It is a potential tool for yield forecasting with respect to climate change scenarios and provides coping strategies to deal with change scenarios. Cost-effective open source/free geographical information and communication technology (Geo-ICT) tools are useful for sensor web enablement and to disseminate information across the rural community, particularly the Line Departments for strategic decision making.

A preliminary study on Precision Irrigation was conducted under shed-net conditions on tomato and potato crops using WSN, Geo-ICT techniques and DSSAT simulation tool. Irrigation requirements and its scheduling were carried out with the help of DSSAT. As a spin-off of this study, climate change scenarios and suggesting coping strategies under different temperature and CO_2 concentration levels were observed, which will be useful to the rural stakeholders to plan contingent measures. However, substantiation of research results on the impact of climate change could be done with long term experiments. Researches are underway to study climate change impact on Rice, Maize & Groundnut crops under semi-arid conditions on crop yield and pest management aspects in a research farm.

2. TOOLS / DEVICES USED

2.1 Wireless Sensor Network

WSN is an emerging technology and it has revolutionized the data collection in agricultural research in obtaining real time data from the field, which will improve the decision–making process to a large extent and help user community to draw contingent measures (Wang et al., 2005). A WSN system consists of (a) cluster of sensor nodes to monitor various processes and environmental conditions, and (b) a base station. A node is generally composed of processors, local memory and sensors. Base station will receive and process the data collected by the nodes and transmits it to the central server using internet connectivity. A typical WSN deployment is shown in Figure 1. The blue spots are the sensor nodes installed in a field which senses the weather/environmental parameters like

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temperature, humidity, CO_2, etc. and will form hotspots and transmit the data wirelessly to the base station. From the base station, one may use ADSL (Asymmetric Digital Subscriber Line) to transfer data to a remote central server. In the current study, two distributed sensing devices were used: FieldServer (FS) and Agrisens (AS).
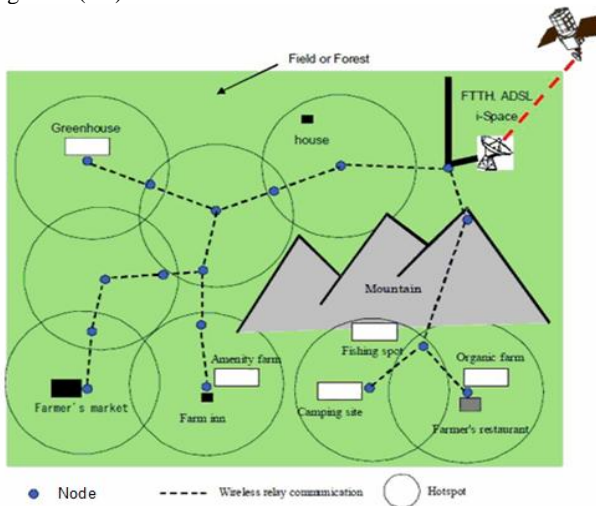

Figure 1. Typical WSN Deployment [Source: Fukastsu & Hirafuji, 2005]

2.1.1 FieldServer (FieldServer, 2009): FieldServer is a distributed sensing device consists of web-server, 24-channels for multi-sensors, web-camera, wireless LAN module and high intensity LED lighting for environmental monitoring. FS deployed in the current study consists of three sensors: ambient temperature, ambient humidity and CO_2 concentration; and a web camera (to observe crop growth/condition). Figure 2 shows the FS installed in the study area.

Figure 2. FS in Study Area

2.1.2 AgriSens (SPANN Lab, 2009): AS is a closed-loop self-organizing wireless sensor network comprising of sensor nodes equipped with an array of sensors that measure, and record data into an electronic database having several variables of interest.

In the present study, AS housed relative humidity and relative temperature sensors equipped with robust self-organizing network infrastructure, signal processing and data prediction algorithms with a secure web portal in it. Typical Agrisens architecture/deployment in Figure 3.

In addition, Wireless Weather Station (WWS) was also deployed in the shed net to argument the research aspects.
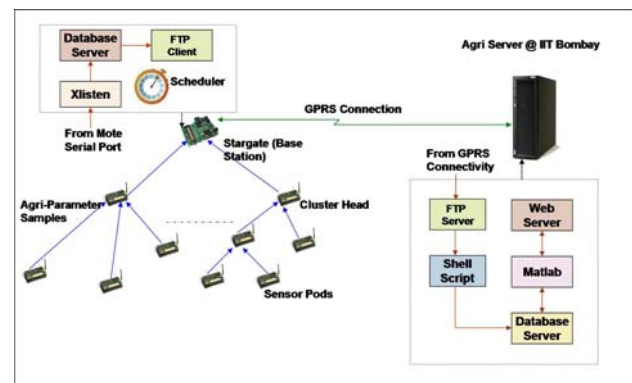

Figure 3. Agrisens Architecture [Source: SPANN Lab, 2009]

2.2 Decision Support System for Agro Technology Transfer (DSSAT) (ICASA, 2009)

DSSAT tool is one of the principal products developed by the International Benchmark Sites Network for Agro technology Transfer (IBSNAT) and is fostered by the International Consortium for Agricultural Systems Applications (ICASA). It is a software package that integrates the effects of soil, crop phenotype, weather and management options. DSSAT includes improved application programs for seasonal and sequence analyses that assess the economic risks and environmental impacts associated with irrigation, fertilizer and nutrient management, climate change, soil carbon sequestration, climate variability and precision management (Hoogenboom, 1994). DSSAT provides the validation of crop model outputs; thus allowing users to compare simulated outcomes with observed results. The DSSAT package incorporates models of 27 different crops with new tools that facilitate the creation and management of experimental, soil, and weather data files. DSSAT includes improved application programs for seasonal and sequence analyses that assess the economic risks and environmental impacts associated with irrigation, fertilizer & nutrient management, climate change, soil carbon sequestration, climate variability and precision management (Hoogenboom et al., 1994). In the present study, CROPGRO model was used to find out the impact of climate change in terms of temperature and CO_2 concentration in tomato crop cultivation.

The future climate scenarios such as increase in temperature and CO_2 concentration were used in the calibrated DSSAT model for the study site to determine the impacts on yield. A hypothetical study was under taken to determine the potential yield of tomato

cultivar Abhinav under 12 different combinations of CO_2 and temperature magnitudes, including the fixed increments in CO_2 concentration in ppm (50, 100, 150) and temperature in ^0C (+0.5, +1, +1.5, +2) individually and with all combinations of different levels. For simulating the effect of temperature change, the daily weather data (T_{max} and T_{min}) were increased by 0.5-2˚C individually in the model and yield was simulated accordingly. Similarly, the climate change scenarios under different levels of CO_2 concentration were applied by changing ambient CO_2 from 50-150 ppm in the model. Possible agro adaptations measures like alternate sowing dates were applied to the calibrated model and their impact on the crop yield was determined. Model was run for different dates of sowing under normal temperatures.

2.3 Geo-ICT

Geo-ICT is an emerging technology that is stemmed from the integration of geo-spatial information and imaging technologies with ICT. It is considered as a core emerging technology that forms a basis for spatial decision making, geo-computation and Location Based Services (GeoICT Lab, 2009). This emerging technology will open up many new applications resulting from a great improvement of data flow efficiency, on-line data processing, management and measurable savings of operational costs.

A web-based distributed collaboration tool, called GramyaVikas was developed to assist the rural extension community in their day-to-day rural development planning decisions (Adinarayana et al., 2008). This cost-effective tool was developed with open-source/free Geo-ICT tools. Plone (Plone, 2000) was used as a document publishing groupware (content management system).

Geo-ICT and WSN technologies together could serve as a viable tool to solve some of the existing problems in dynamic agriculture systems. The advantages of this synergism include: centralized control over data & model; ubiquitous access; interconnectivity; sensor web-enablement; model propagation; educational platform; and interactivity, flexibility and new coordination among the user community with standardization/uniformity.

A WSN module is embedded in GramyaVikas to integrate and take advantages of above synergism. The WSN module contains: Home (description about the current study and potentiality in rural systems); WSN (e-documents/links on WSN technologies, details of FS and AS, to access past/real-time weather data; crop condition/growth images through FS web-camera); DSSAT (DSSAT links, JPEG images climate change scenarios with respect to temperature and CO_2 concentration levels and coping strategies); Irrigation Scheduling (to calculate ET_o/ET_c online on the basis of real-time weather data for irrigation requirement/scheduling) sub-modules. Extension officers and decision makers in agriculture and environmental monitoring fields are the intended beneficiaries of this integrated tool.

3. TEST BED

In order to test and validate the impact of climate change on agriculture using the potential WSN & Geo-ICT tools, tomato (*Abhinav*) & Potato crops were chosen and grown under shed net conditions at IIT Bombay. Figure 4. shows the image of the test bed with latitude and longitude values using Trimble Geo XT GPS receiver in standalone mode. Potato crop wad damaged due to early blight and rodent attack. Hence, experiments were carried out only with tomato crop in the present study. Two FSs and two ASs were deployed to cover the entire plot in the shed net.
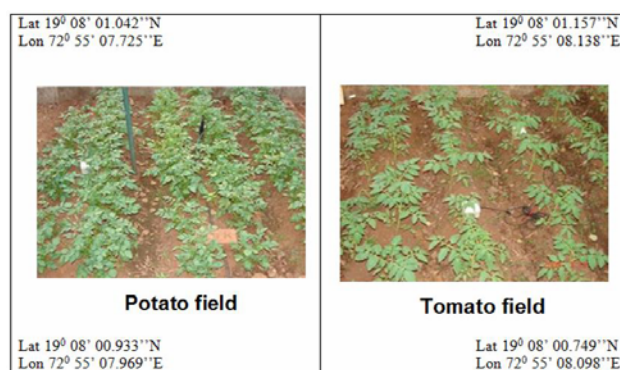

Figure 4. Test Bed with Tomato and Potato Field

4. EXPERIMENTAL RESULTS & DISCUSSION

4.1 Wireless Sensor Network

In the climate change analysis, two major parameters, with the data sampling interval of two minutes, were used: ambient temperature (from both AS & FS) and CO_2 concentration (from FS). These served as input parameters for DSSAT modeling. WWS data supplemented whenever gaps from WSN data was observed.

The maximum/minimum/mean temperature and CO_2 concentration from WSN devices are shown in and Figures 5 and 6, respectively. The maximum and minimum temperatures recorded from WSN were 42.2 and 17.8 ^0C, respectively. The mean temperature for the entire growing season was 25.9 ^{0} C. Figure 5 shows that the concentration of CO_2 was very high during the mid-season stage due to the vigorous growth. The maximum, minimum and mean CO_2 concentration observed during the crop growth season were 946.29 ppm, 693.8 ppm and 772.5 ppm, respectively.

4.2 Decision Support System for Agrotechnology Transfer (DSSAT)

CROPGRO (crop growth) simulation model of DSSAT was used to simulate the yield of tomato crop at different levels of temperature and CO_2 concentration. This model was also used to suggest coping strategies under various temperature regimes.
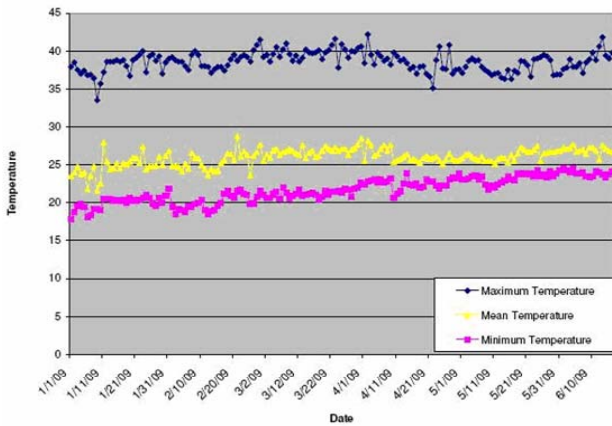
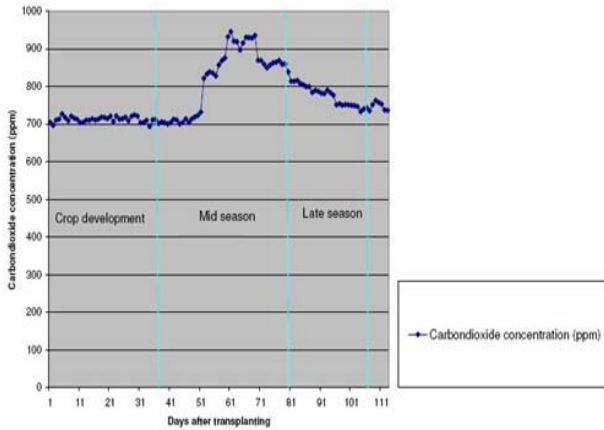Figure 5. Maximum, Minimum and Mean Temperatures During Crop Growth Season

Figure 6. CO_2 Concentration from FS During the Crop Growth Season

4.2.1 Calibration of CROPGRO-Tomato: The CROPGRO - Tomato model was calibrated by the results obtained from WSN technology. The calibration of the model for a specific region and variety is essential for further simulations and climate change analysis. In the current study, calibration was carried out with only one season data. However, if require long term experiments to compute reasonably accurate genotype coefficient values. File containing 'genotype confinements' was used to estimate the genetic coefficient of *Abhinav* variety of tomato crop.

4.2.2 Climate change scenarios: CO_2 is a component of plant photosynthesis that influences biomass production. It also regulates the opening of plant stomata and, therefore, affects plant transpiration. As a result, plants growing in increased CO_2 conditions will produce more biomass and will consume less water. The yield variations of tomato was simulated through the crop growth model with the combinations of CO_2 and temperature levels with fixed increments in CO_2 concentration (50, 100 and 150 ppm) and temperature (ambient, +0.5, +1, +1.5 and +2 ^{0}C) levels. Maximum and minimum CO_2 concentration levels observed were 946.29 ppm and 693.8 ppm, respectively. These concentration levels were used as a base to simulate the climate change scenarios.

It is observed that the simulated tomato yield decreased gradually due to an increase in temperature. Increase in CO_2 level increased the tomato yield and at the same time increase in temperature from 0.5 to 2 ^{0}C decreased tomato yield considerably and consistently. On the contrary, an increase in CO_2 level at any particular temperature increased the grain yields (Table 1). Variation in tomato yield with increase in average temperature and CO_2 concentration levels during normal growing season is shown in Figure 7.

Decision makers can plan their future strategies and plan contingent measures with respect to climate change scenarios in terms of increase in temperature and CO_2 concentration levels by making use of sensory data in the field in real time mode and with the simulated results obtained from DSSAT.

4.2.3 Coping Strategies: Stochastic dominance (SD) rules of DSSAT were used to evaluate the decisions about (simulated) finding the proper transplanting date. These fairly simple management options were chosen to illustrate the methodology of combining crop modelling with SD.

CO_2 Concentration (ppm)	Temperature ^oC			
	+0.5	+1	+1.5	+2
50	2638.5	23166	20238	17968.5
100	29815.5	26185.5	20460	20460
150	33066	28990.5	226	22638

Table 1: Variations in Tomato Yield with Increase in Temperature and CO_2 Concentration Levels

Simulation of the effect of change in transplanting date was carried out using the CROPGRO model to investigate a suitable agronomic option for adaptation under the climate change scenarios. The effect of adjusting the transplanting dates for tomato was simulated by using the experimental results. In the current study, transplanting of tomato seedlings were done on 18th February 2009 and the yield obtained was 25900 kg/ha. This transplanting date and yield were taken as the reference for the study. The transplanting dates were varied in a five day interval and their effect was simulated keeping the above date and yield as reference date of transplanting. For determining optimal transplanting date, simulation was done with 5 days incremental level between 19th January and 15th Match (Figure 7). It is observed that January 19th gave the highest yield of 30657kg/ha and March 15th depicted the lowest value of 22951 kg/ha. From this graph a decision maker can make a reasonably good choice on the date of transplanting.

It has been observed that yield was considerably decreasing as the transplanting date is progressed. This may be due to the high temperature regimes in later stages of the growth. This observation is also in conformity with observed values of yields with increase in temperature as depicted in Table 1. For tomato crop, in this specific location, it is advised to transplant the crop in the beginning of January under the given conditions.
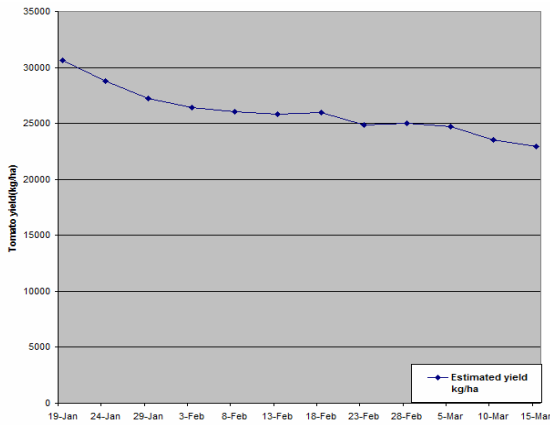
Figure 7. Effect of Transplanting Date on Tomato Yield

4.3 Geo-ICT

Real time as well as past records on various climate parameters at every two minutes from WSN can be accessed in the WSN module of GramyaVikas. A decision maker can make use of this data for irrigation scheduling, pest management aspects, yield forecasting, etc. as well as to monitor the crop growth (from web camera) ubiquitously. In addition, a provision is made in the DSSAT sub-module of WSN module to demonstrate the applicability of DSSAT in climate change on the basis of temperature and CO_2 concentration variations. The results obtained from DSSAT model is incorporated in the module through JPEG images (Figure 8). Various recommendations and coping strategies according to climate change scenarios studied are also available in the module to the users. General processing flow of the present studies is shown in Figure 9.
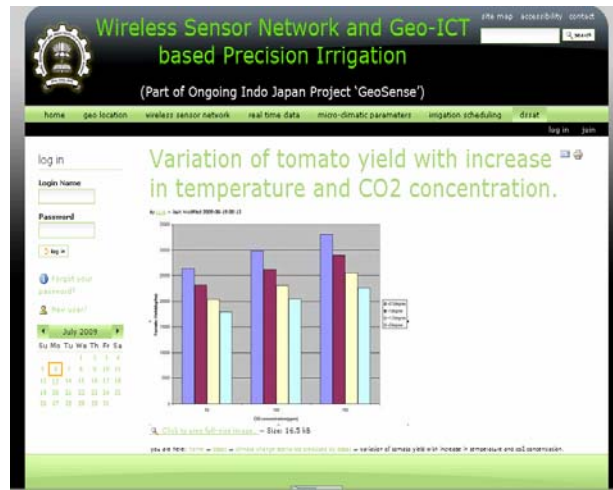

Figure 8. DSSAT Module Showing the Static Pictures of Variation of Tomato Yield with Increase in Temperature and CO_2 Concentration Levels
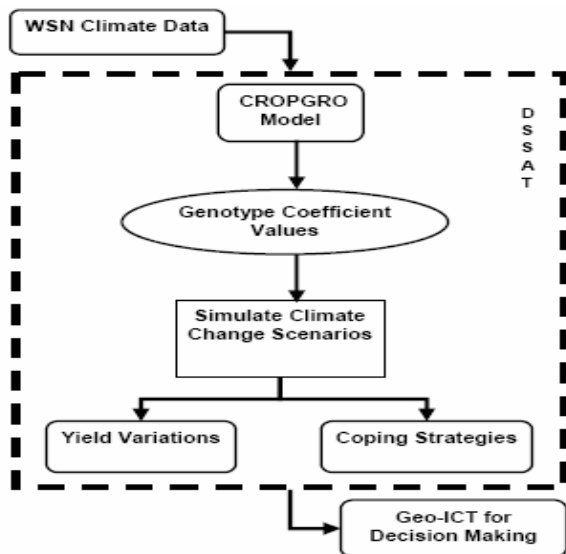

Figure 9. Processing Flow of Utility of WSN, DSSAT and Geo-ICT for Climate Change Studies

CONCLUSION

Preliminary results obtained from the present study, using climate information gathering and analysis tools such as WSN, DSSAT and Geo-ICT under micro-climatic conditions, has demonstrated their utility to understand the climate change scenarios and planning the coping strategies to counter the risks. However, the decision making could be improved with long term experiments.

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