A Software Model for Precision Agriculture for Small and Marginal Farmers

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***Abstract*—Precision Agriculture (PA) was originally developed to address variability in soil and crop parameters for large-scale agriculture in developed countries. The general concepts of PA can also be adapted for farm-based agriculture for small and marginal farmers in Developing Countries. This approach is characterized by a farmer-soil-crop database acquired from the field, crop calendars provided by agricultural experts, real-time acquisition of parameters such as temperature and rainfall through sensors, and an analytical model that simulates the crop calendar using static, semi-static and dynamic inputs, leading to farmer- and crop-level support advisories delivered through devices such as mobile phones and tablets.**

***Keywords*-Precision Agriculture; Variability Control; Small Farmers; Knowledge Modelling; Real-time monitoring; agriculture expert system; crop calendar modelling; mobile-based advisories;**

I. Introduction

Precision Agriculture (PA) is one of the most important developments in the domain of agriculture in the last two decades, from the perspectives of resource and nutrient use, efficiency, and ecological impact. Precision Agriculture primarily attempts to manage—by measurement, analysis and appropriate action—both spatial and temporal variability of soil and crop parameters, with the objective of optimizing profitability, sustainability and protection of the environment.

PA employs multiple traditional and emerging technologies such as automation & robotics; Geographic Information Systems (GIS); Global Positioning Systems (GPS) and Remote Sensing (RS); Sensor Technologies; Wireless Sensor Networks and decision-support and modelling software [1].

PA has been largely used in the context of large farms in the US, with extensive use of GPS and soil monitoring sensor networks. Further, although PA has been used in the context of Developing Countries, this usually refers to Greenhouse-based industrial farming which uses sensors to precisely measure inputs such as water, fertilizer or pesticide. PA has not been hitherto used in the context of open farms—especially homestead farms—for farmers with small and marginal holdings, especially those in Developing Countries.

This paper describes a model that applies PA principles to small, open farms at the *individual farmer and crop* level, to effect a degree of control over variability. While the level of 'precision' achieved may be lower than the original definition, this approach has the advantage of bringing in the benefits of centralized expertise on farm management to the individual farmer.

While the model has been designed around the scenario in Kerala State, India—where the average holding size is much lower most of India—it can be extrapolated to any region with marginal modifications.

A. Precision Farming in the Indian Context

Precision farming originated in the 1980s in the US, where large farms of different crops are usual. In the context of the US, precision farming referred to measurement of different parameters at the micro-level and addressing the deficiencies through automated means. This approach requires extensive baseline information acquired through remote sensing, GPS and related GIS technologies, and also highly mechanized approaches to the entire crop cycle from farm preparation to harvest.

In the Indian context, such a level of precision may be difficult on account of the lack of access to micro-level information. However, some of the principles of precision farming may still be applicable in India. The approach here would be to empower individual farmers with proactive advice that would enable them to take action that would optimize the parameters such as nutrient distribution, irrigation/fertigation/chemigation, and pesticide use.

B. Kerala's Specificities

Kerala has several specificities in the context of agriculture as practised today as compared to the rest of the country. The prime difference is in the nature of holdings: In Kerala, in 1966-67, the average farmer's holding size was 0.72 ha, with 55% of holdings below 0.4 ha. By 1971, 72% of the 54.18 lakh holdings were under 0.5 ha, while 84% were under 0.5 ha by 1991. [2]

Another specificity of Kerala's agriculture is the predominance of multi-cropping. In fact, except for rice and plantation crops, the entire agriculture of Kerala may be considered as multi-crop.

A third feature of Kerala's agriculture is that a significant proportion of farming is homestead-based, garden-land farming (as opposed to wetland farming). Several factors have contributed to this, including the geography, demography and the land reforms on the mid-20th century.

These aspects of Kerala's agriculture sector makes it difficult to address the individual farmer and aid him in the management of his crop, or for area-level synchronized planning for downstream activities such as market interventions, processing or value addition, in particular, for crops for shorter length such as vegetables.

Today, given the widespread availability and percolation of ICTs and network edge-devices (such as mobile phones, tablets/slates etc), it is possible to address the individual small/marginal farmer and provide her with valuable services. This paper proposes a software-driven model for providing PA advisory services to individual farmers for each of their crops.

II. Model Overview

The overarching objective of the model is to deliver direct advisory services to the smallest farmer at the level of his/her smallest plot of crop, using the most accessible and available technologies such as SMS and email.

A. Model Parameters

The overall model simulates a crop calendar with static and dynamic information, and identifies action points for each registered crop for each farmer. The information inputs are the following:

- *Static Information* The crop calendar (ie., the lifetime event cycle for a crop from preparatory phase to harvest phase) for each crop with durations for each phase of the crop, as well as the risks for each phase (eg., pest attack) or eventuality (eg., monsoon failure). This information is provided by agriculture experts.
- *Semi-dynamic Information* This refers to the a database of all farmers registered for the programme as provided below. Each time a crop cycle is over and a new crop is planted on the same plot, the database is updated with the yield and other parameters as specified by the agriculture experts.
- *Dynamic Information* Real-time information based out of sensors or from secondary sources (rainfall, temperature, soil pH). While PA requires decentralized deployment of sensor networks for accurate assessment, this is infeasible in the context of small farmers in developing countries. The use of sensors are therefore limited to parameters for a whole micro-region (a village, or a *Panchayat* in the Indian context), measuring gross parameters such as temperature, rainfall and wind velocity

The model takes these inputs tracks the growth of each crop of each farmer, and provides individual advisories as follows:

- Informational-General: This is usually information of a general kind, for example extreme weather or market advisories
- Information-Specific: This is crop-specific information contingent upon an event. For example, the mitigating the risk of plant death due to five consecutive nights of very low temperatures. It may also include market information for the particular farmer's crops
- Action-Specific: These advisories provide information for a particular crop of each farmer (eg., optimum time for certain operations such as weeding or application of specific fertilizers)

Farmers are requested to provide information back to the model as well. These include:

- Any specific issue for the notice of the community of experts
- Yield at the time of harvest so as to accumulate historic data over a period of time

This model is particularly suitable for shot-term crops such as vegetables, which are in any case the most popular crops for small farmers. The short-cycle length allows a historic database to be built up reasonably quickly.

B. Database parameters

At the technology level, this requires the following parameters of *each holding* to be registered as a database:

1) Size of holding
2) Type and variety of crop item Date of planting
3) Farmer's name/ID
4) Farmers's mobile phone number and email ID
5) Farmer's
6) Location of holding (lat-long, using GPS)
7) Category of the holding (in terms of soil chemistry, water content etc)
8) The type of terrain (categorized on an appropriate basis)
9) Farmer's organization (such as co-operative) with email and SMS contacts

C. Secondary data

The system also requires secondary data as follows:

1) Categorization of holdings on the basis of system appropriate for crop management
2) The soil chemistry and crop management parameters of each category
3) The normal weather conditions of the location category

D. Real-time data acquisition

The system requires the following real-time parameters to be acquired through hardware sensors (these may not be available at the holding level, but at an aggregate level such as a *panchayat*-level:

1) Temperature
2) Humidity
3) Rainfall

E. Hardware and Sensor requirements

The additional hardware that the end-to-end model would require, for both data acquisition as well as advisories, are the following:

1) Sensors for acquiring soil/ambient parameters of temperature, humidity, and rainfall (add additional sensors for pH, NPK levels etc if available)
2) Sensor control unit with SIM-card for GPRS transmission
3) Solar charger plus battery for stand-alone sensor control unit
4) IP Camera for field monitoring
5) Cloud-based Server for tracking parameters
6) SMS gateway
7) GPRS-based gateway for incoming sensor data

Of these, the sensor kit (sensors+control unit+ solar charger + IP camera) would be required one per control area (such as a village or *Panchayat*), although for the ideal case of precision farming, one set of sensors per holding would be required. *The single Panchayat level-sensor could be treated as a representative metric for the entire village if it is appropriate*

F. Process flow

The model process flow for the pilot project is as follows:

1) Two to three georgraphical suitable units (such as *Panchayats*), each containing about 20-30 vegetable farmers are chosen. A 50-cent farm within the University is required as a control unit. Ideally, each unit would have a farmers' organization or co-operative through which the project would operate
2) A consultative meeting of farmers from the selected areas is convened, the project objectives communicated and requirements elicited
3) The database parameters are collected from the participating farmers (even if some of them have already started growing the crop and others are yet to start)
4) A central database is created using an RDBMS such as PostgreSQL (on account of its geospatial capabilities). The database scheme is described in the section on Software
5) Decision-triggers are identified. These include:
   - A particular stage in the crop cycle that needs farmer's intervention (eg., for fertilizer, weeding or application of pesticides)
   - A trigger from the real-time sensors indicating crossing of a threshold (eg., moisture falls below a control threshold, excessive rainfall is detected)
   - Predictive inputs, such as intimation of extreme weather (such as cyclone or drought)
6) The model tracks the crops of all the holdings and provides direct messaging when each trigger-condition is encountered *at the holding level* for each farmer. The messages could include:
   - SMS: Such as 'Tomatoes: Moisture too low – watering required', 'Cowpea: Time for first weeding', or 'Alert: Heavy rains predicted for next 3 days'
   - Email to individual and/or Co-operative, when certain conditions occur. For example, when drought occurs, it may be necessary to notify both the farmer as well as the co-operative of mitigation measures (such as use of mulch)
   - All types of messaging will be tried out in feature-phones, Smartphones as well as Android tablet devices (such as Akash in India or 'One-Tablet-per-Child' programme in Thailand)
7) Records of inputs (fertilizers, pesticides) as well as a track of the weather conditions, the total duration of the crop, and the final harvest quantities will be entered and maintained in the system for analysis; subsequently, the model can also utilize these parameters for optimization
8) At the end of season, a meeting of the project team and farmers will be convened in order to evaluate the performance of the system and calibrate the model
9) At the end of the season, recommendations of crops for the next season can also be provided based on the location and soil & nutritional condition of the holding

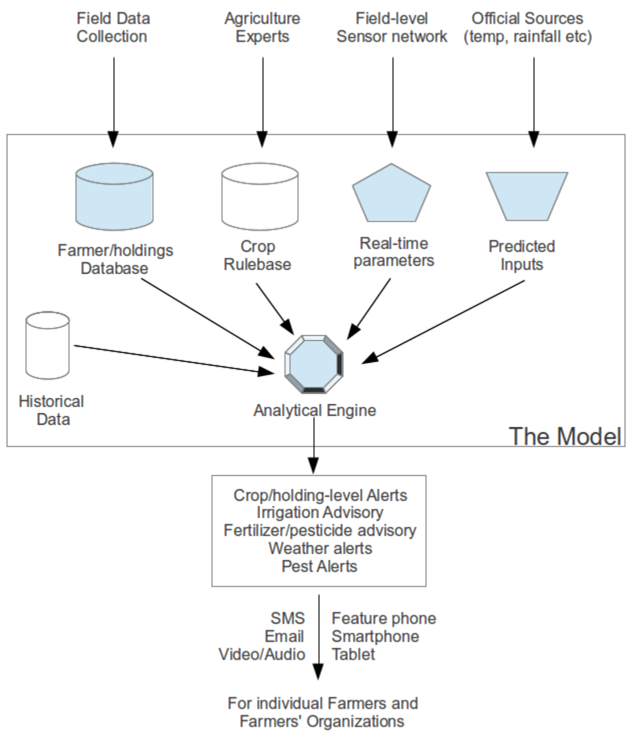

Figure: Schema of Project Functionality

III. Modelling, Software and Hardware Requirements

A. Software and Model Components

The entire project is driven by the underlying software model, which has the following components:

- The master database of holdings of farmers as specified earlier
- Location categories and location-specific requirements of different crops
- The calendar of each crop (provided by agriculture experts)
- Broad weather patterns for the locations of the project
- Sensor information populated into a transaction database
- Parametrized model information based on calendar as well as sensor information
- Triggers and SMS message module for various eventualities
- Simulator module for checking model functioning
- Historic database on crop parameters
- Smartphone/pad/tablet apps for dissemination of services to farmers
- Email based documentation/video distribution for additional services

These software components can be built easily using Free and Open Source Software (FOSS) tools.

B. Hardware components

The main hardware component involved is the sensor unit consisting of components enumerated earlier. There is a requirement of R & D for assembling a unit capable of the following tasks:

1) Initialize the system with an ID and location parameters (static information)
2) Acquire parameters from the atmosphere and/or soil through sensors at programmed intervals
3) Transmit these at regular, pre-defined time intervals through a GPRS-based system through an HTTP Post to a cloud-based backend
4) Be able to measure these parameters on an on-demand basis from the central control
5) Monitor the field-level situation using the IP camera
6) Diagnose the status of the system periodically and report anomalies and abnormalities
7) Diagnose the status of the solar charging system and provide early warning of failure

Open Source Hardware is available that can be used for the development of the system, including sensors available in the market, coupled with a hardware board such as Raspberry Pi or an Arduino derivative, which allow for programmability.

IV. Conclusion

This paper outlines a software driven model that attempts to empower farmers—especially small and marginal farmers—by providing crop-level, actionable information for farmers that be used by them for enhancing the profitability of their crops, reducing crop vulnerability; as well as in reducing negative environmental effects of excess use of fertilizer and pesticides.

While the model is designed taking into consideration the specifics of agriculture of the Kerala region of India, the same principles can be applied to small and marginal farmers everywhere in the country.

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