*e*SAP: A complete ICT solution for crop health management

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Abstract: eSAP (Electronic Solutions against Agricultural Pests) is an unique product successfully addresses current challenges in agricultural sector by translating expertise into practice at farmers' door step in terms of prescription based plant protection, sustainability of soil and inputs to policy makers for scientific assessment of crop health over a region. It successfully integrates different agricultural sub-systems through an ICT solution leading to effective crop management solutions for farmers of India. It generates rural employment and food security contributing to Sustainable Development Goals. The project has been deployed in Karnataka state involving Agriculture Universities, State departments and ICAR institutions. It was widely appreciated as the most innovative solution in crop health programme with focus on sustainability. The project received wide acclaim during the FAO-ITU led e-Agriculture Forum at Bangkok in 2016. It is the recipient of "WSIS 2018 Champion" award instituted by UN-ITU forum. It is one of the finalists in the Manthan South Asia awards for 2016. The project is also figuring in ITU-T study group case studies on e-agriculture.

Key words: eSAP, information communication technology, crop health management, pest surveillance

Crop health management is a complex subject. It majorly encompasses problems caused by and solutions for various pestiferous species of insects, viruses, fungi, bacteria, nematodes and weeds, and nutritional deficiencies that decrease crop production and impact farmers' welfare. There are numerous pests that affect each crop, and not all impact in equal propensities at any given space and time. They vary with soil type, short- and long-term weather patterns, physiography, cropping history, cropping pattern, cropping practices and such external influences. They are also impacted by other competing pests, predation, emigration from and immigration into the agro-ecosystem. Further, the host plant itself responds to pests differently in different space/time situations and affects the dynamics of pests. All these add significantly to the complexity of pest dynamics.

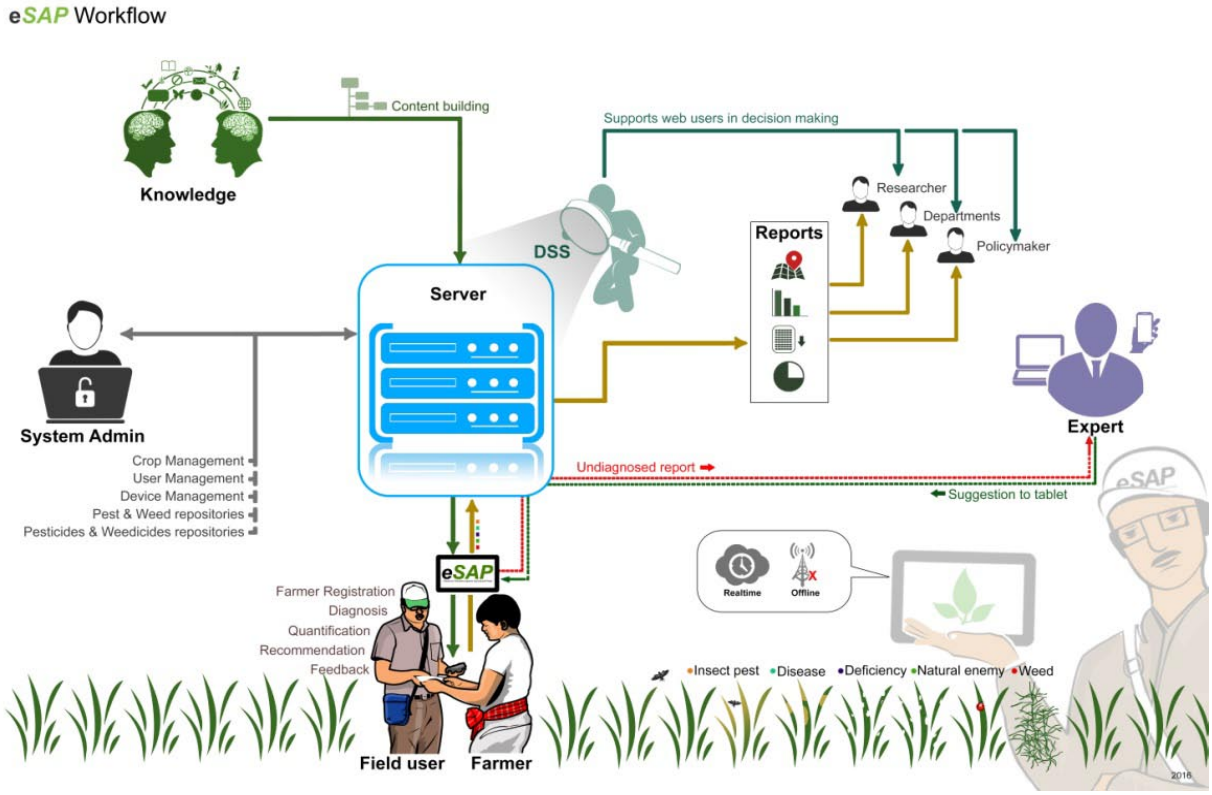
On the other hand, pest management options are equally complex. There are many microbial, botanical, chemical, cultural, mechanical and biological methods. There are many techniques and tools for administering these methods to manage pest populations. Some of them are ecologically sensitive, while some are part of the humble natural world; some are economical, while some are expensive; some methods suit

intensively managed agriculture, while some others suit extensive farming systems, and a mismatch could have dire consequences on the society, like large-scale ecosystem poisoning.

Further, it is often observed that farmer preferences play a significant role in the selection of management strategies. Some look for organic methods, some for inorganic, some prefer cultural and biological, while some others are open to any effective management action. All such variations should be taken into consideration while suggesting remedial actions. Moreover, there is a constant influx of new pest management tools and molecules into the market. These too need to be used appropriately so that farmers and the Nation accrue the maximum benefit. Therefore, pest management is an extremely challenging and complicated section of agriculture.

Current Scenario of Pest Management in India

It is common to find farmers in India visiting pesticide-selling retail shops, with or without samples of diseased plants, and purchasing the 'remedies' sold by the retailer. More often than not farmer ends up buying excessive pesticides and unnecessary crop health enhancers, and without certainty that the concoction would resolve the problem. This is a very dangerous scenario.



Just imagine the condition of the society if the medical world too had done the same — dumped a variety of medicines in the patient's body without diagnosing and quantifying his disease! In the agricultural world, farmers' capital expenses increase without any assurance of crop improvement (which has other serious ramifications — increased and ill-assured capital expense can result in undesirable social consequences). There is a significant increase in environmental pollution and raise in health

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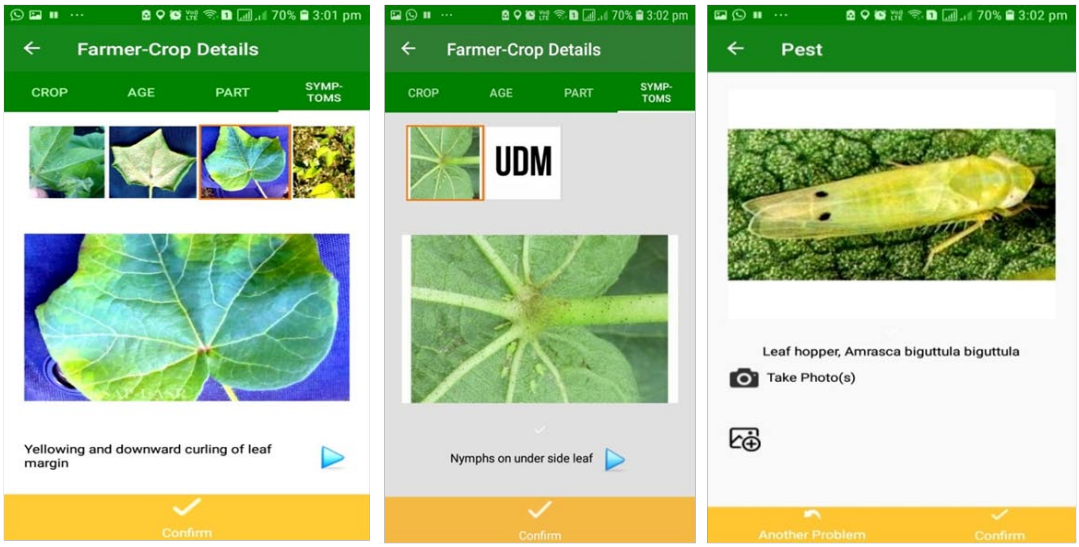
issues concerning farmers and consumers. All this is because the farming society in India does not have access to timely and accurate crop health diagnosis and management.

Electronic Solutions against Agricultural Pests (eSAP) — a prudent choice

eSAP is a path-breaking ICT system dedicated to crop health management. Insect pests, microbial diseases, nutritional deficiencies, and weed problems are covered in the current version of eSAP. Further, it enables the enumeration of different species of natural enemies, which have gained importance during recent times. The potential of eSAP is such that any new agricultural technology can be communicated in an extremely effective manner, in real-time to the field; and, field situations across space and time are instantaneously made known to the managers/policy makers/researchers. For instance, if a new pest management strategy has to be disseminated to many field workers spread across a vast geography, a press of a button in some remote location would ensure instantaneous delivery to all of them. The platform can disseminate information built in various forms like videos, animations, images, text, and audio. Further, spatial coordinates of the field are instantaneously reflected on a GIS map along with extent of severity of the problem. Additionally, such data are presented in automatically updated graphs and tables that enable real-time monitoring of field situations. Inbuilt intelligence aids the process of decision-making so, that biases are minimized and decisions are based on authentic, verifiable field data. Concurrently, this system will ensure the seamless integration of different players in the agricultural ecosystem – field users, subject experts, managers, policy makers, and so on. This application has been built and successfully tested and put to practice for the first time in India by the University of Agricultural Sciences (UAS), Raichur, Karnataka.

The features can be briefly summarised as follows: eSAP is an application built on a platform that opens a gateway for two-way dissemination of information in real-time. Central to the platform is a handheld device that i) provides field users with all the relevant information in their hands; ii) information can be accessed offline; iii) information is intelligently metamorphosed into a form that can be easily understood and put to use by illiterate users transcending language barriers; iv) it has substantial in-built intelligence for on-field decision support; v) it has protocols for intelligent surveys and data collection; vi) specific information on any/all devices can be updated remotely that makes real-time dissemination possible; vii) there is real-time expert connect to handle emergencies and unknown field situations; and, viii) all forms of data, including multimedia, can be disseminated in both directions in real-time. The platform enables policy makers, researchers, and users at the other end of the spectrum to obtain field information in real-time. Field



data that streams-in is viewed over GIS platform. There are automatically updated graphs and tables along with decision-support intelligence. It is multidirectional, flexible and scalable.

The platform has these essential components – (i) handheld field device: it contains the application and content; has ability for multimedia data capture; can send and receive data in 2G/3G/4G/Wi-Fi modes; can be operated in the farms irrespective of the availability of network; (ii) web-based application: it would enable retrieval and presentation of data generated from field devices; forms the entry point for agricultural content to be disseminated to the field devices; provide GIS/other graphical reports from the data generated; enable device management; (iii) expert application: this is available exclusively to experts who are designated to resolve the few undiagnosed problems that might arise from the field. The experts shall be able to exchange opinions among themselves through the application and post their responses back to the field device; and (iv) cloud instance: it will enable data storage and retrieval; data analyses; be the single point of contact for the devices; facilitate data/content exchanges between the devices and web (local hosting is also possible with eSAP).

Features that assist field workers

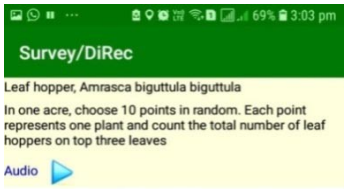
Pest identification

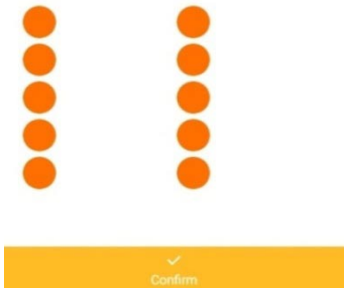
This is one of the most highlighted features of eSAP. The architecture for pest identification follows a unique image-based branching model. High-quality images that characterize pests and their symptoms are adopted to intuitively guide users in identifying the pest. Audio assistance in local language is provided at every step; the user need not be literate. The user merely needs to touch a relevant image at each of the steps to identify the problem-causing organism. The content aims at covering all known pests, so that users are able to identify all pest-related problems in the field itself; dependency on external help is minimal. As the content can be accessed offline, it can be used anywhere, anytime.

Pest surveillance

Pest identification alone is not sufficient to take up remedial measures; it is essential to determine the extent of the pest problem prevalent in each farm. For this purpose, there are intuitively built pest-specific survey forms to quantify the damage caused

by various pests. Data are automatically analysed based on the survey and the pre-determined economic threshold values for each pest. Results and respective suggestions are instantaneously visible on the field device. Depending on this, the user can decide on adopting management strategies or might simply watch for a further buildup of the pest. The survey can be conducted offline too and results can be obtained straight away.





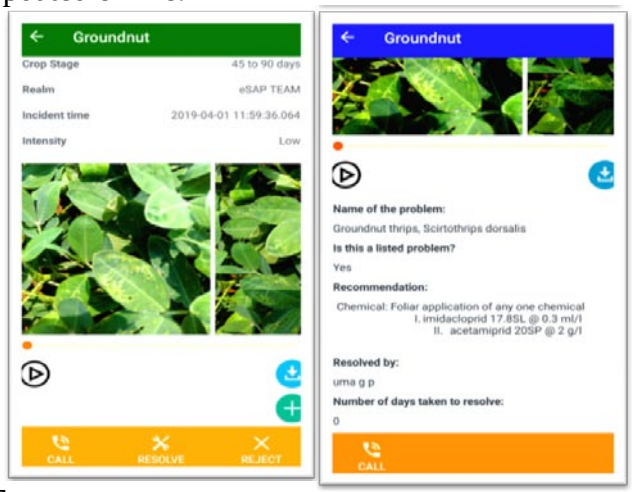
As surveillance entails multiple image capture by the field device, a set of close-ups and field images along with data on the crop, crop age, pest damage and geo-coordinates of the field are transmitted to the cloud for further use by researchers/policy makers. Data transfer occurs instantly on the availability of telecommunication signals.

Pest management

A schedule of recommended management strategies is made available against each pest after determining the extent of the damage. The strategy takes into account the crop, crop age and crop part affected. The user may adopt strategies depending on the automated suggestion made based on the survey conducted. Management strategies are also available offline. Any new strategy, or pest management technology, can be remotely made available on the availability of telecommunication signals.

Pest information

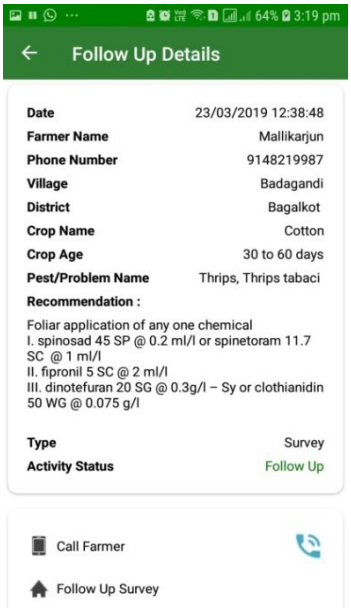
To supplement the knowledge of users, details of pest are made available on the field device, which is available offline and updated online.



Expert connect

Under extraordinary cases, when the available content in the field device is insufficient or the user faces difficulty in using it correctly, expert connect is made available on the device. Here, the application not only enables capture of multiple images of the crop, but also makes

it possible for the user to record his opinion as he speaks. These images and audio files along with other relevant details like geo-coordinates, crop and farmer details are transferred to the cloud in real-time. Designated experts receive an alert regarding the same, and can access information using eSAP web application. The application also allows inter-expert exchange of information before posting their suggestions to the field device. Normally, this process takes less than ten minutes when telecommunication networks are available to all the users.



Feedbacks

As with respect to adoption of technologies and assessment of technologies by field users, provision is made to capture feedbacks in the form of multimedia content, like audio and images, and intuitive grading.

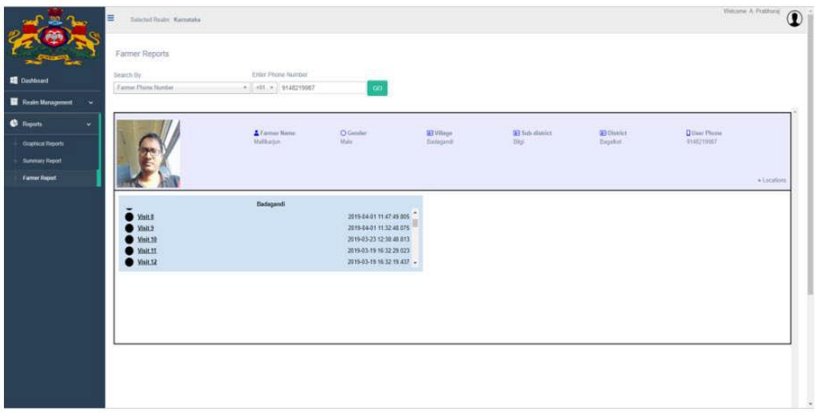
Features that assist policy makers/researchers

Farmer database

An important feature of eSAP is the ability to capture farmer-specific data in the field and build database of the activities of each farmer. All relevant details of farmer, including images, are captured on the field device and a database is created in the cloud, which is accessed through the web application. Every farmer is identified by a unique number with which a log of all his activities across time is created and made available for further use. Also, opportunities to capture any information on farm activity are made available.

Data analyses and reporting

Data captured from various field devices are fed into several databases in the cloud, which are then made available for viewing over the GIS across any defined time and any chosen set of parameters. Users can access automated graphs over eSAP's web application. Points over GIS maps and continuously updated graphs/tables allow real-time monitoring of pest situations across any defined space.



Decision support system

Micro-level decision support system is provided on the field device for taking decisions on pest management strategies to be adopted. eSAP also makes provision for macro-level decision support in the web application. Based on the data generated across space and time, and built-in analyses, alerts for various scenarios can be customised by each web-user, which would warn in several ways – on mobile phones, emails, etc. for taking immediate actions on a larger scale.

Content management

eSAP allows for real-time dissemination of pest management technologies and other information to all/designated field devices. Information on new pests or new information on existing pests, new/modified pest identification routes, additional/new symptoms, new survey plans, and new management strategies can be remotely updated on the field devices over existing telecommunication networks.

Device management

The device part of the platform exploits emerging technologies with capabilities to generate/provide data in a format that an illiterate user can generate/use easy-to-understand multimedia content. Today, telecommunication networks reach a wide spectrum of geographies. However, in the absence of such networks, the device utilises offline storage and delivers content on network availability.

Visible impact of the case study

A study on "*perception analysis of eSAP by farmers in the districts of implementation of eSAP"* conducted by the Extension Department has revealed highly positive response from the farmers (70% of the sample farmers gave positive response) regarding the power of the technology in all aspects of crop protection. eSAP has helped farmers overcome a major difficulty - reliable identification of their crop pest problems. Further, eSAP has effectively driven the concept of quantification of the pest problem and has introduced the concept of pest-intensity based management system. Today, many farmers receiving printed prescriptions carry it to the retailers and demand the same to be given to them. It has a significant impact on the interactions between the pesticide retailers and farmers. Their confidence levels for tackling pest problems have increased. This is largely because of the fact that farmers are completely involved in the identification and quantification process by the extension functionary.

Three more fellow agricultural universities in Karnataka have adopted eSAP. Together, there are more than 1,00,000 farms in Karnataka who have benefitted from eSAP till date. All the horticulture officers of two districts (Ramanagara and Chikkaballapura) provide pest solutions to farmers using eSAP systems. More than 100 extension workers recruited under various projects have received employment opportunities. The opportunities for selling ineffective (and sometimes, spurious) substances has drastically come down. The quantity of pesticides applied has also been according to the prescription, which has reduced indiscriminate usage.

Scientists have discovered many new pest problems in their areas of operation through eSAP. Notable has been the white-

tip disease of paddy and banana skipper. eSAP has a provision for flagging difficult to identify problems in the field, which has resulted in these discoveries. More important has been the fact that identification of the new problems and their management strategies can be disseminated to the field devices in just minutes, such that the field users can henceforth manage these problems by themselves. Certain area-wide decisions have been taken by managers on the basis of data made available in real-time through eSAP system. Notable example has been management of cotton leafhopper resistance in Raichur area. Real-time data showed that the pest population was not declining in the area despite adoption of management strategies. Soon, the expert team found that the population had developed resistance to the pesticide. Administrators, with the help of researchers, decided on changing the strategy. The new strategy was made available on the field devices in real-time, which resulted in successfully managing the pest population before it got escalated to serious levels. Such has been the impact of eSAP.

Deployment of eSAP

Deployment of eSAP technology started since January 2013 after pilot scale studies during 2012 under the aegis of University of the Agricultural sciences, Raichur and has spread to all the districts under other Agricultural Universities in Karnataka. eSAP has reached over 1,00,000 farmers covering 26 crops in all the 25 districts of Karnataka involving all the five (5) agricultural universities.

Today, the need is to draw a holistic picture of pest management for the entire state of Karnataka. Recognizing this, the Government of Karnataka has adopted state-wide implementation of eSAP programme with UAS, Raichur as the nodal centre in coordination with other State Agricultural Universities and ICAR institutions.

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Professor Aralimarad Prabhuraj of the University of Agricultural Sciences, Raichur, Karnataka, India works on insect ecology with special reference to migration and reproductive biology. His other area of research is development of ICT tools to enhance the extension services in crop health management. He and his team has been involved in developing a novel ICT application called e-SAP (Electronic Solutions against Agricultural Pests) which empowers the extension personnel to diagnose and quantify the problems related to insects, diseases, weeds and nutritional disorders in crops and provide solutions on real time. Email: prabhusha2014@gmail.com