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Developing site-specific appropriate precision agriculture

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A B S T R A C T

As conceived in the "West", Precision Agriculture (PA) may be suitable for capital-intensive, high turnover economy, high technology monoculture and controlled management of a single major soil borne pathogen or pest across vast cultivated area but not for the peasant farming or the pest complex ridden unaided agriculture as in India. PA is not about an abstract of characterization. The specific values indicating variations in population at exact grids and helping the individual farmer in decision-making in pest management at varied pesticide doses depending on varied soil pest population intensity and spatial distribution. Often it ends up in reducing the quantum of a pesticide threatened with withdrawal. We understand Appropriate PA (Appropriate Precision Agriculture, APA) as Site-Specific Appropriate Precision Agriculture (SSAPA) applied to cropping system management with geoinformatics and agriinformatics as may be available of land, soil, including its nutrient content and availability of requisite water, meteorology, agrometeorology and forecasting inputs and outputs by marketing, production, protection and processing, and other essential information provided through a decision support system (DSS), in an agriinformatics networking such that is not ordinarily available to Indian farmers in general. Due to Precision Farming (PF), production increased by 40 to 60 percent farmers' margins of the produce and reduction of the commission charged by the middlemen to 7-10 percent. Further, bargaining power, capacity building, optimal crop protection and produce quality were improved and the cost of cultivation has reduced at Agaram Village, Dharamapuri, Tamil Nadu of Adhiyaman Precision Farmers Association (Ramasamy 2007). Their "PA" is a fine example of community or cooperative approach to farming, which has high prospect in India. But it is far from both PA (*sensu lato*) and SSAPA (*sensu* Dasgupta 2006, 2007b) as applied by us in this trial for methodology development. As a prelude to SSAPA we are comparing nine rice- and vegetable-based cropping sequences between improved and farmers' practices in terms of five parameters, viz. crop growth and productivity, soil nutrient management, pest management, (BCA) biocontrol agent balance, and energy balance, economics ~ each with several variables. We are also providing ground and prepare to provide PA –specific data to the farmers. By Return per Rupee invested Rice-Potato-Pumpkin[1], Cucumber-Cabbage-*Basella alba*, and Groundnut–Brinjal+Brinjal sequences were suitable for resource-rich growers, whereas Okra-Chilli+Chilli[2] , and Black gram–Parwal+Parwal sequences were suitable for resource-poor growers. Overall, Groundnut–Brinjal+Brinjal, Okra-Chilli+Chilli, Cucumber-Cabbage-*Basella alba* cropping sequences, over three years in a row, were the best. When information on the detailed soil survey, RS (Remote Sensing) generated geo informatics (Global Positioning System, GPS; Geographical Information System, GIS) including geo-referenced thematic maps, image analysis, geostatistics for spatial analysis, land, soil and physiography, farmers' socio-economic status, meteorological data, crop suitability, crop and pest management, processing strategy and transport, market arrival, demand and price are provided, farmers' decision-making as individuals and members of a given community may become easier and more precise than without.

Introduction

"Precision Agriculture" (PA) applies geoinformatics (GPS, GIS, RS including image analysis and geostatistics) and to manage spatial and temporal variability within and across fields in the site of a vast monocropped area mostly affected with a single pest, associated with all aspects of crop and pest management (Pierce and Nowak 1999, Ristaino and Gumpertz 2000, Melakeberhan 2002, Statford and Warner 2003, Dasgupta 2006, 2007a).

[1] "-" crops in seasonal sequence per year
[2] "+" same crop spread over two consecutive seasons; also underlined

PA has variously been defined as: i) "the application of modern information technologies to achieve Site-Specific Crop Management (SSCM) that means management of a crop at a spatial and temporal scale appropriate to that crop's own inherent variability" (Plant & Roel 2003); ii) "a comprehensive system designed to optimise agricultural production through the application of crop information, advanced technology and management practices"; iii) "Comprehensive Precision Agriculture (CPA) extends between crop planning and post-harvest processing and marketing, to achieve better production efficiency, better product quality, ecological and energy sensitivity and sustainability"; iv) "PA means carefully tailoring the soil and crop management to fit the different conditions found in each field". PA is also referred to as "prescription farming", "site specific farming" or "variable rate technology." PA is a management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production.

More than 58 percent of operational holdings in India have size less than 1ha, multiple cropped, ridden with multiple pests and suffering from dearth from high technology, advisory and agriinformatics networking. On the other hand as Site-Specific Appropriate Precision Agriculture (SSAPA) applied to cropping system management with geoinformatics and agriinformatics as may be available of land, soil, its nutrient content and availability of requisite water, meteorology, agrometeorology and forecasting inputs and outputs marketing, production, protection and processing, and other essential information as a decision support system, such that is not ordinarily available to Indian farmers in general (Dasgupta 2006, 2007a, 2007b; Mandal *et al.* 2007), it is sought to be applied to traditional agricultural system of small and marginal holders constituting 22 million small holders (19 per cent) and 71 million marginal holders making 81 percent of the farming community.

PA is being literally interpreted agricultural concept relying on the existence of *in-field variability*. We understand SSAPA as Site-specific Cropping System Management (SSCSM), rather than in a monoculture system, with all information on the type of soil and its nutrient content and availability of requisite water, weather data, marketing data and information which are all supposed to be applied at the right time, of the right thing, in the right place, in the right way and in right quantity based on analysis, such cannot be applicable except in highly intensive sub-agroecosystem. SSAPA may also be used to improve a field or a farm on the basis of agronomical, technical, environmental and economical perspectives like adjustment of cultural practices (e.g. better fertilization management); better time management (e.g. planning of agricultural activity); reduction of agricultural impacts (better estimation of crop nitrogen needs such as through leaf colour chart implying limitation of nitrogen run-off) and increase of the output and/or reduction of the input, increase of efficiency (e.g., lower cost of nitrogen fertilization practice), betterment of pest management efficacy at reduced cost per unit area, respectively.

Materials and Methods

In Senkapur-on-Ajay, (size of site dependent on the scale of available data) 6 km south-west of Sriniketan [approximately 23°39′ N, 87°42′ E with an average 58.9AMSL, in the alluvial floodplain excluding the river bed inundated every year during the monsoon adjoining the lateritic belt in Birbhum [Western megathermal subhumid subtropical lateritic region. The land was irrigated, located on the northern bank of Ajay in a flood–prone but earth-embanked area in the village called Senkapur. The soil of experimental plot is sandy clay loam, acidic, medium in nitrogen, available phosphate moderate in potash and water holding capacity.

So far we have completed the Site-Specific Cropping Systems Analysis (SSCSA) experiment in a strip plot in 4 m x 3.5 m plots with three replicates comparing nine crop-rotational sequences and practices vis-à-vis farmers' practices and standard recommendations and its analysis by several variables at farmer's field from June 2002–May 2005. Adoption of improved practices, due to farmers' enthusiasm, has been started by them in their fields during the experiment itself such as single pole bamboo staking to tomato, brinjal and chilli, liming of soil, mulching in pointed gourd, split application of nitrogenous fertilizer, incorporation of at least one pulse crop within cropping system management. Now we are providing data about exact location (GPS), physiography, thematic map, normal and current meteorology, detailed soil survey, socio-economic status. We will provide to the farmers in future: data on land use map, marketing data (market arrival, demand and price), crop suitability calculations (on energy balance analysis, local weather trends and normality and impacts on agronomy, economics, pest ecology and market economics), (NBSS & LUP, IMD, Departments of GoWB) as the decision support system (DSS) for the farmers. We would also conduct local survey among farmers using such data and those not using for an *ex ante* evaluation.

Results

After three years of experiment, by return per rupee (RPR) invested, Rice-Potato-Pumpkin, Cucumber-Cabbage-*Basella alba*, and Groundnut–Brinjal+Brinjal sequences proved suitable for resource-rich growers, whereas Okra-Chilli+Chilli, and Black gram–Parwal+Parwal sequences proved suitable for resource-poor growers. Overall, Groundnut–Brinjal+

Table M & M.
Rotational Cropping Systems under study

Treatment	I Year			II year			III year		
	K	R	Z	K	R	Z	K	R	Z
S–1	R–	Po	– Pu	R –	W	– Mb	R –	Mu	– Co
S–2	R –	W	– Mb	R –	Mu	– Co	R–	Po	– Pu
S–3	R –	Mu	– Co	R–	Po	– Pu	R –	W	– Mb
S–4	Cu –	Ca	–Ba	Gn –	Br	+Br	Ok –	Ch	+Ch
S– 5	Ok –	Ch	+Ch	Cu –	Ca	–Ba	Gn –	Br	+Br
S–6	Gn –	Br	+Br	Ok –	Ch	+Ch	Cu –	Ca	–Ba
S–7	Ra –	To	–Am	Ri –	Mi	– Ok	Bl –	Pa	+Pa
S–8	Ri –	Mi	– Ok	Bl –	Pa	+Pa	Ra –	To	–Am
S–9	Bl –	Pa	+Pa	Ra –	To	–Am	Ri –	Mi	– Ok

K = Kharif (Rainy), R = Rabi (Winter), Z = Zaid (Summer), R = Rice, P = Potato, Pu = Pumpkin, W = Wheat, Mb = Mung bean, Mu =Mustard, Co = Cowpea, Cu = Cucumber, Ca = Cabbage, Ba = Basella, Gn = Groundnut, Br = Brinjal, Ok = Okra, Ch = Chilli, Ra = Radish, To = Tomato, Am = Amaranthus, Bl = Black gram, Ri = Ridge gourd, Mi=Marigold Pa = Parwal

Brinjal-Okra-Chilli+Chilli-Cucumber-Cabbage-*Basella alba* cropping sequences, over three years in a row, were the best in terms of return per rupee invested, soil factors (pH, organic carbon), crop phenology and pest factors (dynamics, AUDPC, Pest: NE, management), land occupancy and timely operations (Table 1). Table 2 shows that maximum rainfall occurs in the months of June to September and temperature ranges from 12 to 37 ^{o}C implying wide variation in temperature (De and De 2003). Average RH (%) deviates from normal in different weeks, but high deviation occurs in 11th, 12th and 31st weeks from normal RH. In the soil survey P^{H} ranges 4.30 to 5.20 implying that the upper layer of the soil is acidic and acidity decreases with depth (Table 3). In that area the farmers are mainly small (ca. 41%) and marginal (ca. 45%) with an average land holding capacity of 1.31 ha, but have farming experiences of more than ten years for about 78% farmers in Table 4 (Baral *et al*. 2006).

Table 1
Rice equivalent yield and economics of crops under different cropping systems

Cropping System / Year	Rice equivalent yield (tha^{-1})		Cost of Cultivation (Rs 1000 ha^{-1})		Net Return (Rs 1000 ha^{-1})		Return rupee^{-1} invested	
Senkapur: 2002-2005	IP	FP	IP	FP	IP	FP	IP	FP
S1:R-Po-Pu -R -W-Mb - R-Mu-Co	61.0	57.7	163.0	166.2	141.4	121.6	2.46	2.07
S2:R-W-Mb -R- Mu-Co- R-Po-Pu	63.5	59.9	159.3	166.8	162.5	136.5	2.78	2.20
S3:R-Mu-Co -R -Po-Pu - R-W-Mb	60.4	55.3	159.8	167.4	149.6	115.8	2.60	1.89
S4:Cu-Ca- Ba -Gn-Br+Br - Ok-Ch+Ch	95.3	75.7	221.3	194.8	264.4	188.8	3.49	2.88
S5:Ok-Ch+Ch - Cu-Ca-Ba - Gn-Br+Br	89.1	79.4	204.7	209.2	249.5	195.8	3.39	2.63
S6:Gn-Br+Br - Ok-Ch+Ch - Cu-Ca-Ba	81.0	75.8	182.1	190.4	228.5	193.9	3.74	3.03
S7:Ra-To-Am - Ri-Mi-Ok - Bl- Pa+Pa	62.5	56.9	173.8	184.6	143.1	104.0	2.49	1.72
S8:Ri-Mi-Ok - Bl- Pa+Pa - Ra-To-Am	66.1	61.7	171.9	180.8	161.9	130.3	2.89	2.22
S9:Bl-Pa+Pa - Ra-To-Am - Ri-Mi-Ok	68.9	64.2	188.8	196.8	160.2	127.5	2.71	2.13
S Em (±) AB	0.61	0.61	0.32	0.32	0.32	0.32	0.06	0.06
CD 5% AB	3.73	3.73	1.92	1.92	19.64	19.64	0.39	0.39
S Em (±) AB	0.16	0.16	0.23	0.23	0.71	0.71	0.01	0.01
CD 5% AB	0.49	0.49	0.68	0.68	2.12	2.12	0.04	0.04

See Table M & M and IP = Improved package, FP =Farmers' Package

Table 2

Meterological data* of Sriniketan

Months	Temperature (°C) Maximum	Temperature (°C) Minimum	Rainfall (mm)	Mean Relative Humidity (%)	Sunshine Hours
June	34.77	25.96	244.30	76.48	5.30
July	32.75	25.87	324.96	81.52	4.47
August	32.09	25.77	290.99	84.06	4.82
September	32.19	25.27	249.80	83.29	5.29
October	31.61	22.39	99.60	78.66	7.69
November	29.26	17.28	13.46	71.27	8.28
December	26.14	12.61	8.64	64.75	7.30
January	25.25	11.92	11.37	64.37	7.75
February	28.22	14.44	21.51	58.47	8.28
March	32.93	19.17	32.16	57.40	8.28
April	36.94	23.56	45.59	62.67	8.70
May	37.24	25.03	98.06	68.76	8.51

* Values are mean of 35 years (1966 to 2000) at Sriniketan

Table 3

Soil survey (profile) of the Area

Depth (cm)	pH	E.C.	O.C.	clay (%)	Silt (%)	Sand (%)	Texture
0-9	4.30	0.07	0.62	32	27.2	40.8	Clay loam
9-22	4.90	0.05	0.34	34	31.2	34.8	Do
22-37	5.00	0.04	0.15	30	31.2	38.8	Do
37-61	5.10	0.04	0.12	26	35.2	38.8	Loam
61-92	5.20	0.02	0.09	26	37.2	36.8	Do
92-120	5.20	0.02	0.08	22	31.2	46.8	Do

Discussion

The following information would help the farmers in decision-making at the right time, of the right thing, in the right place, in the right way and in right quantity based on analysis provided with Land use and capability maps and calculations, physiography, marketing arrival, demand and price, detailed soil survey of the experimental plot and the surrounding areas measuring 1, 10, 50 ha blocks with GPS, RS and GIS data, thematic maps on river basin from toposheet (Figure 4), flood records (50 years), crop suitability calculations (on energy balance analysis, agronomy, economics, pest ecology and market economics), normal (35 years) and current weekly and monthly variations (± 1 SD) in meteorology, that will be of help to farmers for planning of agricultural activity *i.e*. crop sowing, irrigation and harvesting. Socio-economic status (before-and-after), pest dynamics (AUDPC) and crop loss estimates on per plant basis (due to multiple pests), comparative pest management practices. Farmers will be able to take right decision which would be of help to establish the SSAPA, such that is not available to Indian farmers in general. Social cost: social benefit analysis on alternative enterprises would help the planners in decision-making. Land use and capability systems focussed on the cropping systems management, suitable location-specific crop production technologies have been developed for tillage. Farmers try to sell the produce at a better price but are often taken by surprise by sudden and inordinate fall in price due to glut in the market, lack of adequate marketing infrastructure etc. The existing marketing system is beset with problems on lack of market information flow, between elements in the supply chain, credit and infrastructure. In developing the supply chain for agricultural produce must concentrate on potential crop production areas, institutional arrangements, quality control, procurement and distribution centre with effective and efficient manner. Overall, agriinformatics networking is yet to develop and reach out to small and marginal farmers.

Most nagging pest and field problems relate to plant pathogens (both biotic and abiotic). Farmers often have to turn to uninformed vested or unethical quarters for pest diagnosis and advices. Consequent to which what meted out are often wrong control measures, wrong pesticides, wrong doses, wrong growth stages, wrong methods, wrong timing, and wrong hours of the day, not to speak of the least precautions and safety measures. The same may be aggravated in the case of the system of intensification of a crop as a rice in three consecutive seasons in a year.

Various factors such as intensive cultivation, mono-cropping, changing weather conditions and indiscriminate use of pesticides have resulted in frequent outbreaks of crop pests causing huge crop losses. Minimising these losses is one way of enhancing agricultural production. Losses can be due to biotic factors, pests and abiotic stresses and disasters such as drought, floods etc.

Overall, community approaches to farming at different levels of cooperation (joint/cooperative farming or cooperation at various levels from planning to disposal) would further strengthen SSAPA, and with more information and knowledge itself SSAPA would also be more strengthened.

Conclusions

1. PA and SSAPA are Site-Specific. PA has been made possible after the United States of Department of Defence (USDD) has permitted use of certain declassified data for agriculture. For the recent past, such data are trickling into Indian agriculture with restricted usage.

2. PA is applied in plots above 6 ha (only one study in EU), to a few hundred ha dimensions. The RS scales have to be narrowed down from 50,000 - 60,000:1 to some suitable scale to be usable for SSAPA for the majority of farmers in India. PA *per se* is applied to monocropped area affected by a single soil-borne major pest. Thus, it may be useful only for monoculture plantation forests, certain plantation crops, major staple crops, some commercial crops like potato, certain monoculture fruit crops and specific vegetables extensively cultivated in certain regions in India.

3. PA is monoculture-specific and aims at a single major pest and reduces pesticide (those under scanner) dose by spot application but SSAPA aims to be suitable for multiple crops or cropping systems for farmers for varied socio-economic status and capability for a developing and transforming country like India.

4. Multidisciplinary approach of agricultural scientists in various fields is needed to study SSAPA more thoroughly ~ whereas PA in the USA, EU, Brazil are actually doing that.

5. In SSAPA, in order to be suitable for the majority of farmers, blocks of individual fields could be treated as a homogenous management unit for the purpose of precision farming. Even then we are trying this to see how much and, if at all, a farmer-friendly DSS as SSAPA can be achieved under the present circumstances.

6. Some encouraging results and techniques have been obtained. Target farmers are enthused, which raises optimism among the researchers.

7. More free access to RS - generated data, extension of agrometeorological and forecasting services, agriinformatics networking and diagnostic, advisory, market situation and related areas, co-ordinate action research efforts etc. are imperative.

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Table 4
Socioeconomic Status of Bolpur, Illambzar and Sainthia Blocks of Birbhum District

Traits	Percent of farmers	Traits	Percent of farmers
Farm size (Operational holding)		**Education profiles of farm labourers**	
Marginal farmer (< 1 ha)	41	Illiterate	87
Small farmer (1–2 ha)	45	Primary level	12
Medium farmer (2-4 ha)	13	Secondary level	01
Semi-medium farmer (4 -10 ha)	01		
Large farmer (>10 ha)	00		
Average size of holdings (ha)	1.31		
Farming Experience		**Profitability of pesticide application**	
Less than 10 years	18	Profitable	58
10+ to 20 years	50	Incurred loss	11
20+ to 30 years	28	Cannot say	31
More than 30 years	04		
Education level (Land owner)		**Sources of technical information to pest control**	
Illiterate	05		
Primary level	12	Pesticide Dealers sales agents	79
Secondary level	71	Neighbour	39
Higher secondary level	12	Relatives	23
		Extension workers	21
		Radio	05
Age profiles of farm labourers		**Protective measures adopted during pesticide application**	
Child labour (below 14 years)	02		
Adult (14 to 60 years age)	93	Cover only face with cloth	40
Senior citizen (above 60 year age	05	Cover only body with cloth	33
		Covers both body & face with cloth	19
		No protection adopted	08

Source: Baral *et al*. 2006; Year of Survey 2004-05