15 years of precision farming in Europe – lessons to be learned for Malaysia

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Summary

Due to recent developments in the Malaysian agricultural sector, which emphases on Precision Agriculture (PA) as one of the strategies to strengthen the industry, the present paper critically examines the potential and limitations of PA for Malaysia based on the experience of 15 years of research and implementation of PA in Europe and the USA. As the Malaysian agricultural sector is divided into large scale plantations and smallholders, technical aspects of PA, such as yield limiting factors and applicability of remote sensing as well as social and infrastructural requirements and economic suitability are discussed for both, the Malaysian rice and the oil palm industry.

Despite the high attractiveness of the PA concept to both scientist and policy makers it has to be evaluated carefully for its suitability to a specific agricultural sector. Whereas technical aspects can be generalized for the entire sector, social, infrastructural and economic requirements are very different when considering either large commercial estates or private smallholders. Technical aspects of PA that need to be considered are firstly the assessment of the crop specific yield limiting factors as PA is based on the assumption that inherent small-scale within-field variability is limiting crop productivity. Secondly, given the climatic conditions optical remote sensing is not suitable for Malaysia, thus alternative ways of assessing within-field variation are needed. Whereas the oil palm industry is supported by a strong governmental framework of R&D, extension services and economic attractiveness and thus is ready to adopt a knowledge-intensive technology such as PA, for smallholders in rice production the lack of bare essentials, literacy, social and physical capital, physical infrastructure and the access to governmental extension services will require major governmental interventions prior to any PA implementation.

Key words: *agricultural sector, oil palm, Malaysia, precision agriculture, rice, smallholders*

Zusammenfassung

Die derzeitige landwirtschaftliche Ausrichtung Malaysias setzt auf Precision Agriculture (PA) als Strategie zur Stärkung des primären Sektors. In diesem Artikel werden das Potential und die Limitationen des Konzeptes PA für Malaysia, vor dem Hintergrund von 15 Jahren Forschung und Einsatz von PA Technologien in Europa und den USA, diskutiert. Die Landwirtschaft Malaysias ist gekennzeichnet von großflächiger Plantagenwirtschaft auf der einen, und kleinbäuerlichen Strukturen auf der anderen Seite. Die technischen Aspekte von PA, wie ertragslimitierende Faktoren und Anwendung von Fernerkundung sowie die sozialen und infrastrukturellen Voraussetzungen und die ökonomischen Rahmenbedingungen werden für die malaysische Reis- und Ölpalmenindustrie erläutert.

Trotz der hohen Attraktivität von PA für Politik und Forschung muss die Eignung dieses Ansatzes für jeden einzelnen Bereich der Landbewirtschaftung Malaysias genau überprüft werden. Während die technischen Voraussetzungen für die unterschiedlichen landwirtschaftlichen Bereiche gleich sind, sind die sozialen, infrastrukturellen und ökonomischen Voraussetzungen sehr unterschiedlich, wenn man Großbetriebe mit der kleinbäuerlichen Struktur vergleicht.

Als technische Voraussetzung müssen zunächst die ertragslimitierenden Faktoren für unterschiedliche Anbaufrüchte bewertet werden, da PA auf der Grundannahme basiert, dass die kleinräumige Variabilität agronomischer Parameter einen Einfluss auf die zu erwartenden Erträge hat. Zweitens begrenzen die klimatischen Bedingungen Malaysias den Einsatz optischer Fernerkundung zur großräumigen Erfassung der teilflächenspezifischen Variabilität in der Landwirtschaft. Alternative Technologien zur Bestimmung der Heterogenität müssen daher zukünftig entwickelt werden.

Während die Ölpalmenindustrie aufgrund der wirtschaftlichen Attraktivität des Palmöls über hohe staatliche Unterstützung in Form von Forschungsprogrammen und Dienstleistungen verfügt und somit durchaus in der Lage ist anspruchsvolle Technologien wie PA einzusetzten, fehlen in den kleinbäuerlichen Strukturen des Reisanbaus jegliche Grundlagen dazu. Hier mangelt es an Basiswissen, sozialem und finanziellem Kapital und technischer Infrastruktur, sowie dem Zugang zu staatlichen Beratern. Grundvoraussetzung einer Einführung und Anwendung von PA sind in diesem Bereich massive staatliche Eingriffe.

Schlüsselwörter: *Kleinbauern, Malaysia, Ölpalmen, Precision Agriculture, primärer Sektor*

Introduction

In the early 1990's "Precision Agriculture" (PA) emerged as a new farming technology, which promised to aid both farmers and society by improving production efficiency and/or environmental stewardship (Schnug et al., 1993a, 1993b). In a nutshell PA represents a re-orientation of conventional farming to a farm management system that takes the variability of natural resources into account in order to protect the environment and to increase the profitability for farmers. Whereas research and political interest in PA is high in both Europe and the USA (Haneklaus & Schnug, 2003; Lowenberg-DeBoer, 2003) adoption of PA by farmers has been modest at best and tends to concentrate in "hot spots", such as the Midwest (heartland) region in the United States and the Eastern parts of Germany (Daberkow & McBride, 2000; Lowenberg-DeBoer, 2003). Despite the growing European and American disillusionment with PA, Asian agriculture is now focusing on PA to curb issues on food security, water scarcity, bio-production and environmental sustainability in the 21st century. Malaysia, which proudly hosted the first Asian Conference in Precision Farming last year specifically highlights the importance of PA in the Third National Agricultural Policy (NAP3, Ministry of Agriculture Malaysia, 1998).

The agricultural sector plays a major but declining role in the Malaysian economy. The contribution of the agricultural sector to the Gross Domestic Product (GDP) is expected to decline from 13% in 1995 to 7.1% in 2010 (Ong Khun Way, 2002). After the economic crisis in 1997 the volatility and resultant decline in the exchange rate of the local currency, the Ringgit, in relation to major currencies negatively affected the stability and security of the country's food supply. Thus, with the NAP3 (1998-2010) the government re-emphasized the importance of the agricultural sector, whereby the overriding objective of NAP3 is the maximization of income through the optimal utilization of agricultural resources. This includes maximizing agriculture's contribution to national income and export profits as well as maximizing income of producers. The strategies employed comprise moderate expansion of land and further intensification of land use, encouraging oil palm, fruit and vegetable cultivation as well as adoption of modern farming technologies (Ministry of Agriculture Malaysia, 1998).

The main objective of this paper is to critically examine the potential and limitations of PA for Malaysia based on the experience of 15 years of research and implementation of PA in Europe and the USA. The Malaysian agricultural sector is divided into large scale plantations basically consisting of three crops (rubber, oil palm and cocoa) and smallholdings, which constitute of about 60% of the agricultural farmland (Ong Khun Way, 2002). The question of whether PA can be used to modernize and strengthen the agricultural sector in Malaysia is discussed separately for the agribusiness on big farms and agricultural production on small farms, exemplary for rice (*Oryza sativa*) and oil palm (*Elaeis guineensis*) production. The paper is divided into different sections, whereby each section addresses one of the inherent problems, which were highlighted in recent reviews concerning the successful propagation and implementation of PA (Batte & Arnhold, 2003; Haneklaus & Schnug, 2003; Lowenberg-DeBoer, 2003; Schnug et al., 2003; Godwin et al., 2003a).

Identifying yield limiting factors

Conventional farming is based on the risk adverse 'null hypothesis that given uncertainty in space and time, uniform within-field treatment is an optimal strategy' (McBratney & Whelan, 1999). In contrast, PA recognizes the inherent heterogeneity of agricultural fields and aims at transferring the resulting site-specific crop demands into variable management practices (Haneklaus & Schnug, 2002). In the early days of PA the ultimate goal was to depict the within-field variability of soil and plant parameters and to adjust tailor-made management recommendations (e.g. Schueller, 1997). After 15 years of practical experience a number of scientists come to the conclusion that it is more fruitful to identify the main processes that limit yield production rather then addressing every small field heterogeneity (e.g. Lark, 2001; Dobermann et al., 2002). Thus, the basis for any economic sound PA strategy is to define basic site-specific limiting factors.

Oil palm appears indeed to be the "golden crop" of Malaysia, with a steady and constant increase in production over the last 10 years. Since the beginning of commercial oil palm planting in 1917, Malaysia advanced to be the leading producer of crude oil palm oil (CPO). However, average yield records of around 3.2 – 3.4 tons CPO ha^{-1} yr^{-1} since 1980 indicate that the impressive growth of palm oil production is mainly a result of area expansions, and not because of an increase in yield (Tab. 1). It is beyond the scope of this paper to give a precise answer as to why the Malaysian fresh fruit bunch (FFB) yield has not improved over the last 20 years, however the authors would like to suggest two aspects of oil palm management that might hamper optimal yield production. The first one is optimal fertilization, the second optimal timing for fruit bunch harvesting. Although, most oil palm estates are practicing some kind of site-specific nutrient management (SSNM), the common practice is to divide fields into management blocks of usually about 20 to 50 hectares with on average 130 oil palms ha^{-1}. Each block is inspected at least annually to assess the nutrient requirement and to provide fertilizer recommendations (Razman Abdul Raof et al., 1999), whereby the average foliar concentration of a mixed sample consisting of about 1 sample per ha^{-1} will represent the entire block. Although the optimal sampling distance varies in different landscapes and for different nutrients it is generally accepted that the observed spatial variability is proportional to the mobility of the nutrient (Cahn et al., 1994). Haneklaus et al. (1997) suggested an optimal sampling distance of at least 100 m for foliar samples and a minimum of 50 m for soil parameters. This means that oil palm plantations are missing the optimal sampling distance by at least one order of magnitude, resulting in "site-unspecific" and thus most likely unbalanced fertilizer applications. In addition, the area and the size of a management block are usually determined by already existing boundaries such as roads or rivers (Razman Abdul Raof et al., 1999). It is unlikely that these blocks represent homogenous management units, as soil variability is a function of localized soil forming factors (Haneklaus & Schnug, 2003). Management units therefore should preferably follow the landscape and not already existing infrastructures.

The second problem is the optimal timing for fruit bunch harvesting. The CPO yield is not only a function of the site-specific yield potential of the palm tree, but also of the right timing of harvesting the fruit bunches. At present there are no scientific sound procedures to test for the optimal harvesting time. As palm trees are producing fruit throughout the year, the optimal harvesting time is different for individual palm trees. At present plantation manager rely strongly on field experience using the color of the fruit bunches and number of fruit droppings as an indication. Suffice to say that this method is flawed by misjudgment and leading to a substantial loss in yield. Both of the above yield limiting factors can be attributed to the inherent variability of the fields, thus in principle they could be improved by appropriate PA technology. Additionally, genotypical differences and age of the trees contribute to different ripening processes and need to be integrated in a prognosis scheme for the optimal harvesting date.

For tropical rice production the situation is different. In temperate cereal production SSNM has shown to be the component widely adopted by farmers (Haneklaus & Schnug, 2003; Lowenberg-DeBoer, 2003). Real time ground sensors provide rapid assessment of within-field variability of canopy reflectance, which often can be related to the nutrient status of the crop (Mohd Noor et al., 2002). PA research in Malaysia appears to follow this trend with launching its first ride-on agricultural tractor in 2004 (Azmi Yahaya et al., 2004). But is SSNM the answer to increase rice production? For irrigated rice Doberman et al. (2002), summarizing on-farm experiments at 179 sites in eight key domains in Asia, concludes that SSNM has a promising agronomic and economic potential, but only if other crop management constraints to nutrient use efficiency are alleviated. Of all cereal crops, lowland rice is probably the one most vulnerable to pest and disease. With 500 – 600 different diseases, numbers reported for tropical rice are an order of magnitude higher than rice production in temperate zones (Swaminathan & Sinha, 1986).

In addition to pests and diseases unfavorable climate conditions pose a serious risk to rice production. (Doberman et al., 2002). About 50% of the total rice area in Malaysia is rain-fed and thus left to the good will of nature. Tab. 2 presents historical data on rice loss in Malaysia due to the occurrence of flood, drought and pest. Although, the Malaysian government invested a substantial amount of money for the implementation and upgrading of irrigation schemes, irrigation efficiency at present is estimated at about 45%, bringing about a conflict between domestic, industrial and agricultural water demand.

Since rice irrigation consumes about three quarter of the available surface water, irrigation water management is becoming a key factor in sustainable yield production (Deepak & Amin, 2002).

The production of high rice yields is further hampered by the wide distribution of traditional planting methods with low yielding local varieties, especially in East Malaysia. For the period 1996 to 1999, 20% of the total rice area was located in Sarawak, where yields only achieved 30-40% of the nations' average (DOA, 2004). It appears that yield limiting factors in Malaysian rice production are external factors that cannot be tackled by addressing within-field variability.

Tab. 1: Malaysia, oil palm, development of harvested area, fresh fruit bunch (FFB) yield and CPO production 1980-2003

		Year				
		1981-85*	**1986-90***	**1991-95***	**1996-2000***	**2001-03****
Area harvested	(100 ha)	10042	15366	20234	26488	31808
Fruit yield	(ton FFB ha^{-1})	17.7	17.2	18.3	18.7	18.1
Oil production	(1000 ton CPO)	17720	26560	37080	49428	57705
(Source: FAO Agriculture Statistics Database, 2004, *5 year average, **3 year average)						

Tab. 2: Percentage of acreage loss due to the occurrence of flood, drought and pest for the 3 main rice producing states in West-Malaysia (1968-1979) (Source: MARDI, 1981)

Year	Kedah	Kelantan	Perak
1968	3.8	6.6	0.3
1969	0.3	0.4	0.0
1970	1.7	4.0	1.7
1971	0.0	2.1	0.1
1972	0.1	3.2	2.1
1973	0.6	2.3	0.0
1974	0.2	17.2	3.5
1975	0.4	4.7	0.2
1976	0.1	2.5	2.8
1977	1.2	2.6	0.3
1978	21.4	0.8	1.1
1979	0.1	1.3	1.0
Mean	2.5	4.0	1.1

Remote sensing and precision farming

Once inherent natural within-field variability has been identified to be the yield limiting factor, this variability has to be assessed and mapped in order to develop site-specific management strategies (Haneklaus & Schnug, 2003). While impressive advances of the agricultural machinery industry resulted in the development of ride-on tractors that are able to perform site-specific weeding, ploughing and fertilization at almost any operational scale wanted, the technology to assess the variability of crop and soil parameters lacked behind. To embrace the entire variation of the field in order to obtain a 'true' image, a high sampling density is needed, which in most cases is not economically feasible or sustainable for farmers (Lowenberg-DeBour & Boehlje, 1996). In the early days of PA remote sensing, either by satellite, airplane or ground sensors promised to be the solution to the problem. Numerous studies were carried out to relate canopy reflectance data to crop fertility (e.g. Curran, 1989) and although laboratory studies showed promising results the use of remotely sensed images in agriculture never really had a breakthrough, as it contains primarily thematic information, but agricultural operations require quantitative values of biological, physical and chemical properties (Haneklaus & Schnug, 2003). Moran (2000) summarized the agronomic demands towards remotely sensed images by preference: image delivery within 24 hours; georeference with an accuracy of one pixel; information accuracy of the measured crop or soil conditions of 70–75%; repeat coverage ranging from twice per week to biweekly; spatial resolution of 10–20m; maps providing quantitative information of measured features; fair product prices.

In Malaysia the use of optical remote sensing for agricultural planning is very limited due to unfavorable climate conditions such as heavy rain and thick clouds (Abu Bakar & Shaari, 1997). Radar remote sensing could be a potential alternative to acquire information of within and between field variation. Studies investigating backscatter response of wetland rice concluded a high potential of this technique for rice monitoring (e.g. Ugsang et al., 2002). For tree crops the application was found to be more restricted as the signal is not only affected by the trees but also by the undergrowth (Hoekman, 1995). In general, the application of radar remote sensing for real time crop management is at present rather limited as it involves long time spans of data pre-processing (Zillmann et al., 2004). As labor shortage is one of the problems, the Malaysian agricultural sector is facing the need to develop effective methods to assess within field variation under tropical conditions.

Social requirements of PA

Tailoring soil and crop management to match local within-field variation is not entirely new to Asian farmers. The growers traditionally noted yield variability both in space and time, and adjusted farm practices according to local site conditions (Srinavasan, 1998). In Malaysia this is reflected in small farm and field sizes of traditional agricultural communities (Ong Khun Way, 2002; Ngidang et al., 2003). However, PA is based on the application of technologies such as Global Positioning Systems (GPS), Geographic Information Systems (GIS), remote sensing, yield monitors and Variable Rate Technology. Implementation of PA means that higher education levels of farmers are required to conduct and follow up the more complicated decision making, and extended knowledge and skills are needed to operate the sophisticated technology (Haneklaus & Schnug, 2002).

The Department of Agriculture 1990 statistics for Peninsular Malaysia indicated that the majority of farmers were more than 55 years old. 25% had no schooling and less than 13% went beyond primary school (DOA, 1990). Although the statistics is more than 10 years old the educational situation, especially among smallholders has not changed much. Dimbab Ngidang et al. (2003) describe a typical rural community in East-Malaysia which consisted of 67.7% of smallholder farmers, the majority (45.6%) of whom had only primary school education, while 30.3% had never been to school at all. In contrast, the Malaysian oil palm industry employs educated people on the plantation management level, while the actual field workers are often from foreign countries and regularly only have primary level education (Chee et al., 1996). Malek Mansoor et al. (1997) reported insufficient human skill as one important factor inhibiting mechanization in oil palm plantations.

Changing from conventional farming to PA the farmer is not only facing high costs for investments that must be incurred up-front, but he is also faced with a large amount of new and complex data. Either the farmer has to adopt knowledge in information and communication technology (ICT) himself or it is outsourced to an agricultural consultant. An European survey assessing the factors limiting the use of ICT by German farmers showed that different appraisals of the factors are made by scientists and farmers. While the scientists saw the cost of technology and the lack of user friendliness as the main problems, the participants of this study thought that lack of training and failure to understand the possible benefits were the greatest impediments (Rosskopf & Wagner, 2003). Dobermann et al. (2001) summarizing the results of on-farm experiments to evaluate SSNM in key irrigated rice domains in Asia stresses that the most important factor for adopting the new technology is how easy it is for farmers to implement without a major commitment of time. An alternative would be to take advantage of the "Local knowledge" (LK), which reflects information, which is available on a farm, either in form of amateurish maps, field files and any other materialized form of store (Haneklaus & Schnug, 2003). But LK comprises also knowledge from personal education, experience or inheritance from former generations. Making efficient use of LK is a great challenge to operate SSNM on all scales. The farmer himself becomes the biological interface between his field and crops and hard- and software components, respectively (Haneklaus & Schnug, 2003). In any case, however, it would be necessary to educate farmers to apply their LK and transform it accordingly into variable rate applications.

Whereas most oil palm estates are practicing some kind of SSNM, the majority of rice farmers do not even employ soil or plant testing to adjust fertilizer applications. In fact, fertilizer practices are mainly driven by the governmental subsidy politics (Fujimto, 1996; Pingali et al., 1998), so that most of the fields receive less fertilizer than the governmental recommendation (Tab. 3).

Tab. 3: Fertilizer recommendation and subsidies for Malaysian rice production (Source: DOA, 1999)

Growth stages	**Fertilizer**	**Nutrient rates (kg ha^{-1})** N	P_2O_5	K_2O
< 3 leaves	Mixed*	44	39	25
vegetative	Urea*	46		
	Urea	16		
	MOP			60
Stem elongation	Compound	30 -33	30 -33	43-53
	Urea	16		
Grain formation	Compound	18-20		26-32
* subsidized				

For rice farmers the willingness to increase the input into the field, be it money wise or time wise is further hampered by the age structure of the sector as well as the land ownership. It appears that the younger generations are no longer interested in taking farming as their occupation. A migration of school leavers to town centers is commonplace. The blame is put on the lack of employment in rural areas and social policy failure, which is urban-biased (Dimbab Ngidang et al., 2003). There are success stories of entrepreneurial farmers, who have mechanized their operations and grouped small farms together into units large enough to take advantage of economies of scale (Fujimoto, 1996), but the overall picture is a decline of rice farming throughout the country (Fig. 1).

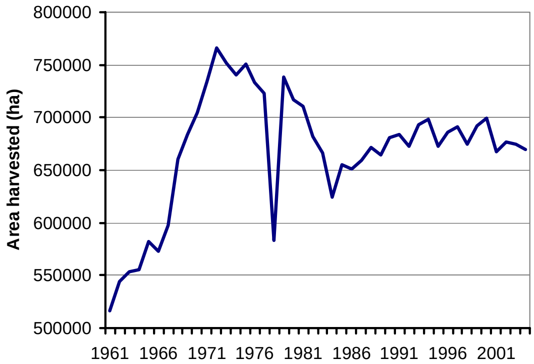

Fig. 1: Trend of Malaysian rice production based on area harvested since 1960’s. (Source: FAO Agriculture Statistics Database, 2004)

Profitability of PA

Profitability of PA has been identified as one of the key factors that determine its implementation (Atherton et al., 1999; Swinton & Lowenberg-DeBoer, 1998; Lambert & Lowenberg-DeBoer, 2000; Godwin et al., 2002b). The potential benefits of managing crops using precision farming techniques can be summarized as: (1) the economic benefit of an increase in crop yield, and/or a reduction in inputs, i.e. seed, fertilizer and agrochemicals, and (2) the environmental benefit from a more precise targeting of agricultural chemicals (Godwin et al., 2002b). These benefits have to be offset against the costs of assessing the variability in soil and crop parameters and special equipment to implement variable applications. Most economic studies on PA have been done on SSNM and show a clear link between crop value and profitability of the practice (Lowenberg-DeBoer, 2003). The profitability of SSNM is clearly linked to the cost of fertilizer (Haneklaus & Schnug, 2003) as well as farm size and inherent within-field variability of nutrients (Godwin et al., 2002a).

The Malaysian rice industry is strongly supported by the government via subsidies. A survey conducted by the Department of Agriculture in Sabah revealed that in the main producing rice area, labor was the most expensive input for farmers (Tab. 4). In comparison, the bulk expenses for oil palm estates is led by the cost for fertilizers and their application (Mohd Noor, 2003). Thus, the relative cost of fertilizers is much higher in the oil palm industry than in the rice industry. This implies that reduction of fertilizer input will not be the driving force for Malaysian rice farmers to adopt PA.

Tab. 4: Cost of rice production (RM) per hectare for Kota Marudu, Sabah (Source: Abd. Azaziz Hj. Abd Latif, 1998)

	Year				
	91/92	**92/93**	**93/94**	**94/95**	**95/96**
Fertilizer	138	117	128	119	138
Pesticides	52	34	71	84	132
Termite Poisoning	47	32	50	27	32
Labor cost	543	641	477	430	339
Ploughing	247	247	247	247	247
Seeds	28	32	39	44	52
Total cost	1056	1102	1013	952	941

Schnug et al. (2003) conclude that in a situation where the share of fertilizer and pesticides in the total crop production costs are constantly declining substantial benefits from managing the variability of soils can only be expected if either the implementation costs for PA, or the labor cost can be reduced. For Malaysian rice farmers the main factor that exalts production cost is farm size. DOA (1999) estimates that 65% of all rice farms in Malaysia are less than 1 hectare in size while only 4% are larger than 3 hectares. It is suffice to say, that for the majority of rice farmers implementation costs for PA will not be economical. However, an agricultural reform which would lead to the consolidation of farms is actually contradictory to the basic concept of PA, whereby farms should be managed as small homogeneous units (Schnug et al., 1993a). Land consolidation, with the aim of increasing average farm and field sizes will definitely increase the spatial variability of fertility parameters since land use has persistent, multi-decadal effects on the spatial heterogeneity of soil resources (Fraterrigo et al., 2004).

To reduce production costs transborder farming (Auernhammer, 2001) could be a potential concept for the Malaysian rice industry as it is designed to make PA applicable in regions with small-scale farming. Neighboring small farms are treated as one large farm, whereby ownership structures remain unchanged (virtual land consolidation). Tillage, cultivation and harvesting are organized in larger units disregarding existing boundaries. Model calculations for Bavaria showed that the size of headland was reduced between 15 and 25% and effective working time by 20 to 30% (Auernhammer et al., 2000).

It is important to note that although PA aimes at the entire crop production cycle, starting from ploughing, seedling, fertilizer and pesticide application to harvesting, European and North-American farmers only implemented "some stand alone precision farming technologies" such as Yield Monitors and Variable Rate Fertilizers so far (Batte & Arnholt, 2002; Haneklaus & Schnug, 2003; Lowenberg-DeBoer, 2003; Schnug et al., 2003). At present there are no truly integrated precision farming systems (Lowenberg-DeBoer, 2003). Malaysia seems to be following this trend as for oil palm and rice both assigned research institutes, the Malaysian Palm Oil Board (MPOB) and the Malaysian Agricultural Research and Development Institute (MARDI) have incorporated PA as one of their strategic research areas but until now research is mainly focusing on the development of variable rate technologies (for example Azleen et al., 2002; Wahid et al., 2004; Chan, 2002; Chan, 2004).

According to Lowenberg-DeBoer (2003) PA is not economical if only applied to one aspect of the crop production cycle. He gives the example that "the interaction of the right corn hybrid at the best population for that hybrid with the profit maximizing nitrogen rate for that hybrid and population, can yield better and may be more profitable than if each input were optimized separately".

Important in this context is the concept of the site-specific yield potential (Rogasik et al., 2002). Even for the interaction of the right oil palm hybrid at the best population for that hybrid with the profit maximizing fertilization rate for that hybrid and population, no increase in yield can be expected if the field chosen for planting is not suitable for the growth of the oil palm. Jalani et al. (2002) already states extension of palm areas to Class 3 (marginal) and 4 (unsuitable) soils as one of the reason why Malaysians oil palm yields are stagnant.

Infrastructural Requirements

In general, technological innovations are likely to be more knowledge-intensive when compared to traditional farming practices. Technological innovations are based on more efficient use of inputs with recommendations tailored to specific groups of farmers and narrowly defined production environments (Alex et al., 2002). Apart from profitability the main reasons for the slow adoption of PA techniques by farmers have been identified as: lack of willingness to commit management time (Lowenberg-DeBoer, 2003), lack of training (Rossenkopf & Wagner, 2003) and frustration with the hardware, software and procedures of the system (Batte & Arnholt, 2003). Thus it appears that knowledgeable intermediaries are essential before PA techniques can be implemented on a larger scale. It is generally accepted that the use of intermediaries to disseminate important agricultural information to farmers has been for years an integral part of agricultural development strategies as well as agricultural research (Winrock, 2003).

Whereas most oil palm estates have their own R&D units, which are closely linked to the Malaysian Palm Oil Board, one of the leading international research institutes for oil palm, rice farmers depend strongly on the extension services provided by the Malaysian Department of Agriculture. Apart from the rice industries the Department of Agriculture is also responsible for fruits, vegetables, herbs, coconut and flowers. Over the last couple of decades, attention on rice has taken a backseat, which is reflected in low numbers of rice experts in the country. At present the Department of Agriculture lists only six in-house rice experts (DOA, 2005).

According to Rahim M. Sail et al. (2004) agricultural extension services in Malaysia have been focusing more on transfer of technology than on human resource development. Following a centralized top down approach farmers are seen mainly as recipients of technology rather than trained as individuals who should be capable of using knowledge (or technology) to achieve their goals. However, only educated and empowered farmers are able to verify the suitability of technologies coming from sources outside their environment. They have the capability for generating and developing technologies suitable for and directly applicable in their local specific agro-ecosystem and for maximizing the productivity of their farming system (Padmanagara, 2004).

Extension services to support PA implementations by smallholder farmers need experts with knowledge of both agriculture as well as PA techniques. Although a variety of tertiary educational institutes offer courses related to agriculture, postgraduate spatial information education is only offered at one university in Malaysia and here not by the agriculture, but the engineering faculty. According to Abdul Rashid Mohamed Shariff & Zulhaidi Mohd Shafri (2005) Malaysia is facing a lack of professional manpower with essential qualifications in GIS and remote sensing to take a leading role in the universities as lecturers and researchers.

Conclusions

To strengthen its agricultural sector Malaysia is challenged by a very heterogeneous agricultural industry. Despite the high attractiveness of the PA concept to both scientist and policy makers it has to be evaluated carefully for its suitability to a specific agricultural sector. Whereas technical aspects can be generalized for the entire sector, social, infrastructural and economic requirements are very different when considering either large commercial estates or private smallholders.

Technical aspects of PA that need to be considered are firstly the assessment of the crop-specific yield limiting factors as PA is based on the assumption that inherent within-field variability is the yield limiting factor. Secondly, given the climatic conditions optical remote sensing is not suitable for Malaysia, thus alternative ways of assessing within-field variation are needed.

As for the non-technical aspects of PA the oil palm industry is supported by a strong governmental framework of R&D, extension services and economic attractiveness and thus is ready to adopt a knowledge intensive technology such as PA, whereas for smallholders in rice production the lack of bare essentials, literacy, social and physical capital, physical infrastructure and the access to governmental extension services will require major governmental interventions prior to any PA implementation. Without these interventions, especially regarding the build-up of human capacity, PA by itself will not be the key to modernize and strengthen the agricultural sector in Malaysia, but it will widen the social division within the sector and marginalize the smallholders even more.

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