Sustain Sci
DOI 10.1007/s11625-013-0219-3

ORIGINAL ARTICLE

The relative importance of factors influencing the adoption of sustainable agricultural practices: a factor approach for Malaysian vegetable farmers

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Received: 16 January 2013 / Accepted: 8 May 2013

Abstract This study develops the understanding of the adoption of sustainable agricultural practices (SAPs) by investigating the relative importance of a set of multidimensional factors in the Malaysian vegetable production sector. A factor approach is deployed to identify explanatory indicators within an integrative framework that is synthesized from the theory of interpersonal behavior and the theory of diffusion of innovation. We achieved this by analyzing a logistic regression model for the adoption of six individual SAPs (conservation tillage, intercropping, cover crops/mulches, crop rotation, organic fertilizers/composts, and integrated pest management). The findings indicate that adoption depends on a range of socio-economic, agro-ecological, institutional, informational, and psychological factors, as well as the perceived attributes of SAPs. Fundamental policy understanding of the issue should, therefore, be multidisciplinary. In addition, standardized coefficients reveal that the impact of statistically significant factors on adoption is unequal. In general, the most influential factor is the asymmetric distribution of resources across geographical locations. This is followed by financial capital and a number of factors, including the workforce size, the usefulness of information, Chinese ethnicity, and the perceived relative advantage of SAPs. Guided by this prioritization understanding, future SAPs promotion now has a better opportunity to target the more important areas. Similar research effort should be made to steer sustainable agriculture internationally.

Keywords Adoption · Sustainable agricultural practices · Multidimensional factors · Relative importance · Policy

Introduction

The adoption of sustainable agricultural practices (SAPs) is crucial to improving agricultural sustainability (Reimer et al. 2012). However, there is a broad consensus that their adoption rates have been low in many countries. Therefore, understanding this phenomenon is essential to maximize SAPs adoption.

Many studies have attempted to understand what leads to the adoption of SAPs. Their findings, as reviewed by Baumgart-Getz et al. (2012), Tey and Brindal (2012), Prokopy et al. (2008), Knowler and Bradshaw (2007), and Pannell et al. (2006), collectively suggest that adoption depends on a range of socio-economic, agro-ecological, institutional, informational, and psychological factors, as well as perceived attributes.

However, some scholars believe that this body of research may have reached its limit in contributing to a refined understanding, particularly in respect to the voluntary uptake of SAPs (Knowler and Bradshaw 2007). They argue this because the current state of knowledge is

Handled by Fusuo Zhang, China Agricultural University, China.

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Published online: 22 May 2013

not easily transposed to policy (Higgins and Foliente 2013).

To overcome these caveats, this study posits a better understanding of the issue through two modifications in research methodology. Primarily, a set of common factors from the six identified dimensions provides a fundamental knowledge from multiple perspectives (Tey and Brindal 2012). This is crucial to our understanding, since farm decision-making involves multidisciplinary considerations (Conway 1985). Secondly, the prioritization of statistically significant factors can indicate which of them is more important, thus, demanding more attention. Both initiatives will steer policymaking towards a more guided format.

It is our objective to refine understanding of the adoption of SAPs by identifying the relative importance of a set of multidimensional factors. The first element can be achieved by linking various factors to economic decisions (Lynne et al. 1988). The second element can be realized by comparing the magnitude of standardized coefficients (SCs) of statistically significant factors. To demonstrate these, survey data from Malaysian vegetable farmers are analyzed to yield policy implications for fostering agricultural sustainability.

Literature review

According to the reviews by Baumgart-Getz et al. (2012), Tey and Brindal (2012), Prokopy et al. (2008), Knowler and Bradshaw (2007), and Pannell et al. (2006), common factors that influence the adoption of SAPs can be split into six dimensions: socio-economic factors, agro-ecological factors, institutional factors, informational factors, psychological factors, and the perceived attributes of SAPs.

The socio-economic dimension characterizes farm operators' management capacity. Common managerial factors include those related to human capital: gender, age, education levels, ethnicity, and experience. Male farmers often have greater access to, and control over, resources, especially in developing countries (Kassie et al. 2009). Older farmers have a shorter career horizon. Higher education levels empower farmers with greater ability to manage new ideas vis-à-vis their associated risks and benefits. Informal farming knowledge could be culturally rooted according to ethnicity (Elkind 1993). Greater experience could also lead to better assessment of investment, but farmers may have lost their knowledge of SAPs when embracing farm mechanization (Kloppenburg 1991). As such, most of these factors are expected to exaggerate adoption, but ethnicity and experience are uncertain factors.

Since SAPs are labor-intensive, labor plays a key role in farm management. Larger household size means greater availability of labor. Farm workers can also be hired from external sources. They increase management capacity given that SAPs do not lend to themselves towards easy mechanization. Both of these factors are likely to facilitate adoption. However, a different reaction may arise when farmers are already busy working long hours (Shamsudin et al. 2010).

Stronger fiscal capacity to make investment and afford any losses resulting from adoption is expressed as greater financial capital (Guerin and Guerin 1994). Livestock provides additional farm income or savings through its composted manure that can be sold or save farm input costs. Alternatively, wealth can be raised through off-farm employment and farmers' spouses (Ogunlana 2004). Other external financial sources include access to credit and loans. Farm size can also operate as a proxy to wealth: larger farms have economies of scale, greater productivity, and higher farm incomes. When financial aptitude is bolstered, farmers have greater capacity to invest in, and undertake, the risks of SAPs.

Asymmetry in a farm's agro-ecological endowments will alter the farmer's likelihood to adopt SAPs. Steeper farms are more susceptible to erosion and inputs runoff. The same threats are also more prevalent in highlands. The presence of such environmental challenges poses a threat to agricultural productivity. An additional challenge for farmlands that have been used for a longer period is how to maintain or improve soil quality while being used. These issues are likely to be handled via the adoption of SAPs. In particular, organic farming tends to rely on SAPs that are also known as natural resource management practices. Similarly, self-owned land will be managed more sustainably than rented land and be passed to successors. While it is impossible to capture all farm-specific characteristics, farm region is used to depict the differences of natural resource quality across regions (D'Emden et al. 2006). The effect of farm region upon adoption cannot be a priori known.

External factors which influence the inclination towards the adoption of SAPs are characterized as institutional factors. Social networks such as farmer associations and cooperatives are particularly influential. Members' common SAPs are expected to be followed by others. Various sustainable standards are also stipulated in certification programs (e.g., Organic and Good Agricultural Practices Certification Scheme). To qualify, participants have to perform the required practices. Certain requirements have to be fulfilled in institutional arrangements (e.g., contract farming). More often, they focus on the timely supply of produce and quality. Therefore, the participants tend to minimize risk by avoiding new production practices.

Information is disseminated through both informal (e.g., other farmers) and formal sources (e.g., extension services). Though accessible information has generally been assumed to be useful, little is known about its degree of usefulness. To capture this concept, when information is useful, farmers must be assumed to have had access to particular sources, to have understood the information, and to have been able to make use of it (Larson et al. 2008). They can be captured under the heading of perceived usefulness of information. Relevant information on SAPs should lead to their adoption: the more relevant it is, the more likely that adoption will occur.

Psychological factors could be crucial when SAPs do not offer immediate benefits (Lynne et al. 1988). Intention is formed after a comprehensive consideration of motivational (e.g., expectations and positive feelings) and non-motivational factors (e.g., time and capital). The expression of strong intention represents a higher degree of desire to realize environmental-related behaviors (Lamba et al. 2009). The behaviors could be a matter of personal habit (Stern 2000). When SAPs have been practiced, they should be repeated.

Because of the nature of human reasoning, the attributes of SAPs must be perceived subjectively by those considering their adoption. According to Rogers (2003), relative advantage describes the degree to which SAPs are seen as more beneficial than competing practices; compatibility considers the degree to which SAPs are consistent with existing values, past experiences, and needs; complexity centers on the difficulty in understanding and use; trialability concerns the degree of experimentation on a limited basis. Favorable perceptions toward relative advantage, compatibility, and trialability are likely to be linked to adoption. Greater complexity, as perceived, should be negatively related to adoption. As such, what matters is how farmers perceive an attribute of SAPs.

Conceptual framework

Understanding the complexity of farmer behavior could be improved by linking multidimensional factors to economic decisions (Lynne et al. 1988). For achieving this, behavioral theories have been used to provide a base to partner with other theories. Recent examples include an integration of the theory of planned behavior and the theory of diffusion of innovation (DOI) (Reimer et al. 2012; Tutkun et al. 2006) for explaining the adoption of sustainable practices, the theory of reasoned action and the pest-belief theory (Heong and Escalada 1999; Heong et al. 2002), as well as the theory of interpersonal behavior (TIB) and the structuration theory (Feola and Binder 2010) for probing pesticide application.

Our conceptual framework (see Fig. 1) is built upon Triandis' (1977) TIB and Rogers' (2003) theory of DOI. Both theories are compatible (Jackson 2004). They offer a theoretical ground to capture socio-economic, agro-ecological, institutional, informational, and psychological factors, as well as perceived attributes. Most of these dimensions are captured by the TIB. A single exception is perceived attributes, opening the door to seeking theoretical support from the origin of the dimension—the theory of DOI.

In our conceptual framework, the position of perceived attributes coheres with mental processes in the TIB from two

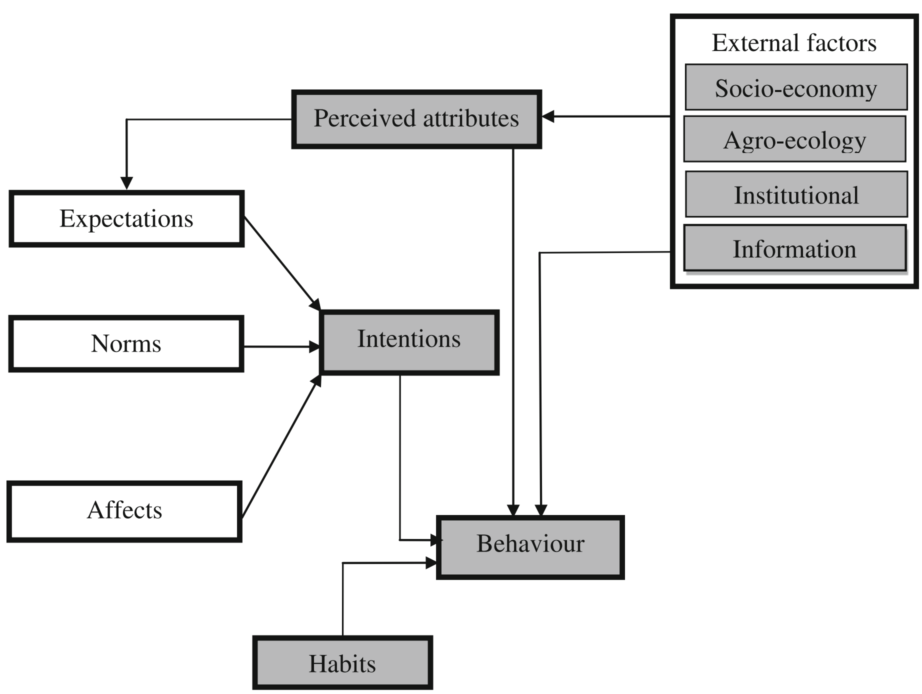

Fig. 1 The integrative framework of Triandis' (1977) theory of interpersonal behavior (TIB) and Rogers' (2003) theory of diffusion of innovation (DOI). Note that dimensions which are included in the factor approach are *shaded*

perspectives. First, perceptions are influenced by the characteristics of potential adopters (Rogers 2003). These characteristics are those that fall within the socio-economic, agro-ecological, institutional, and information dimensions. Second, perceptions lead to beliefs (Pannell et al. 2006). Beliefs here refer to the cognitive content of the outcomes of carrying out a behavior in the form of expectations. These pre- and post-components of perceived attributes are similar to Reimer et al.'s (2012) hybrid framework.

Through the lens of the TIB and the theory of DOI, factors influencing the adoption of SAPs can be investigated using a "process" approach or a "factor" approach. The "process" approach aims to explain the processes shaping adoptive behaviors. When psychological factors prove to be exceptionally significant, such an indirect investigation offers insights into mental and emotional interventions. Alternatively, the "factor" approach identifies independent variables that explain a dependent variable directly (Kurnia and Johnston 2000). It is an effective method for generating policy implications. Given our interest in identifying what factors lead to adoption, the factor approach is employed in this study.

In the factor approach, the adoption of a single SAP is measured as a dichotomous choice. It is a function of socio-economic, agro-ecological, institutional, informational, and psychological factors (habit and intention), as well as perceived attributes. Those in socio-economy, agro-ecology, institutional, and information may either facilitate or impede adoption due to their asymmetrical distribution. Habit represents an established behavior. Adoption should be repeated if it has already been practiced. Perceived attributes are a form of subjective evaluation. Positive ones are likely to yield adoption. Intention indicates the strength of the willingness to perform or continue a behavior. Strong intention is likely to exaggerate adoption.

Methodology

As noted above, the factor approach was chosen to identify important explanatory factors for the adoption of an SAP. The shaded boxes in Fig. 1 represent these factors. They can be translated into a subjective utility model (Bayard and Jolly 2007). Adoption is likely to happen when the subjective utility of the action is greater than that of its competitor. The probability (P) model can be presented as:

$$P = f(se, ae, it, if, ps, pa) \quad (1)$$

where P is the probability of adoption of an SAP, se is a vector of socio-economic variables, ae is a vector of agro-ecological variables, it is a vector of institutional variables, if is a vector of informational variables, ps is a vector of psychological variables, and pa is a vector of perceived attributes.

Estimation methods

In this study, farmers make a decision to adopt or not to adopt an SAP. Given such a binary choice, a logistic regression is used to explain the probability of occurrence (e.g., Herath and Takeya 2003; Cramb 2006). The dependent variable (y) is truncated at both ends: at 0 (non-adoption) and 1 (adoption). The probability (P) that $y = 1$ can be expressed as:

$$P(y = 1) = \frac{\exp(b_0 + b_1x_1 + b_2x_2 + \cdots + b_ix_i)}{1 + \exp(b_0 + b_1x_1 + b_2x_2 + \cdots + b_ix_i)} \quad (2)$$

where x is a vector of independent variables and b_i are the unstandardized coefficients. Given that P is the probability of adoption, then $1 - P$ is the probability negated. The odds for adoption are $(y) = P/(1 - P)$ and its log odds (called logit) is $\log(y) = \log[(P)/(1 - P)]$. These considerations transform the non-linear equation Eq. 2 into a linear equation, which can be written as:

$$\log(y) = b_0 + b_1x_1 + b_2x_2 + \cdots + b_jx_j \quad (3)$$

Estimation of Eq. 3 produces a set of unstandardized coefficients. Statistically significant ones are seen as important. They are interpreted just as unstandardized coefficients in multiple regression (Hair et al. 2010). For example, a 1 % increase in an independent variable will lead to a 5 % change in the corresponding dependent variable. However, such a change has little meaning for non-natural metrics (e.g., an interval scale of agreement levels). Because different metrics are used by various factors, unstandardized coefficients also do not provide a standard to compare their relative importance within a regression.

Subsequently, SCs were estimated. That estimation was based on Menard (2011), who wrote "…a single best approach to the construction of a standardized logistic regression coefficient [is]…" to estimate the variance of $\log(y)$ through:

$$V_{\log(y)} = V_{\log(\hat{y})}/R^2 \quad (4)$$

where $V_{\log(\hat{y})}$ is the variance of the predicted values of $\log(y)$ and R^2 is the explained variance. The square root of Eq. 4 yields the standard deviation of $\log(y)$ and can be written as:

$$\mathrm{SD}_{\log(y)} = \mathrm{SD}_{\log(\hat{y})}/R \quad (5)$$

where $\mathrm{SD}_{\log(\hat{y})}$ is the standard deviation of the predicted values of $\log(y)$ and R is the correlation between the observed values of y and the predicted values of y. By placing Eq. 5 into the formula for the SC of the log form of multiple regression [$\beta_i = b_i(\mathrm{SD}_x)/\mathrm{SD}_{\log(y)}$], standardized logistic regression coefficients (β_i) can be calculated as follows:

$$\beta_i = b_i(\mathrm{SD}_{x_i})R/\mathrm{SD}_{\log(\hat{y})} \quad (6)$$

where b is again the unstandardized coefficient of the ith independent variable, SD_{x_i} is the standard deviation of the ith independent variable, R is again the correlation between the observed values of y and the predicted values of y, and $\mathrm{SD}_{\log(\hat{y})}$ is again the standard deviation of the predicted values of $\log(y)$.

According to Menard (2011), SCs are useful for two reasons. First, they allow a meaningful interpretation for natural and non-natural metrics: how many standard deviations of change in a dependent variable are associated with a standard deviation of change in the independent variable. Second, they help distinguish the relative importance of statistically significant factors: a higher absolute value of SC indicates a greater impact of an independent variable on the dependent variable.

Study area

This study was carried out in all five regions (the Northern, Central, Southern, East Coast, and eastern regions) within Malaysia, with an estimated population of 8,250 involved in vegetable production. Tropical and temperate varieties are grown in the lowlands and uplands, respectively. Their production operates on an intensive basis in open farming. Their reliance on non-renewable inputs is often associated with externalities.

Chemical pesticides, as one example, are often inappropriately applied. On-farm contamination degrades the quality of vegetable produce and soils. The effect on soil may dissipate over time (Chai et al. 2009), but contaminated produce often reaches the market unless violation of maximum residual limits is detected (Taylor et al. 1993). Potentially, this problem is compounded because of the cumulative effect of some of these residues in the human body. Off-farm contamination dilutes the quality of water resources. This poses health risks to consumers through polluted water and fishery products (Leong et al. 2007).

Improving sustainability is a key goal in the Tenth Malaysia Plan (2011–2015) and a blueprint in the New Economic Model (2011–2020). These policies direct concerted effort into further encouraging the voluntary adoption of six generic SAPs that have been promoted fragmentally and during varying time periods: conservation tillage, intercropping, cover crops/mulches, organic fertilizers/composts, crop rotation, and integrated pest management (IPM). Like other countries, the adoption rates of these SAPs have been limited (for details, see Tey et al. 2012a). To advance their progress, it is timely to understand the adoptive behavior concerning these SAPs and enhance their future promotion.

The selected SAPs aim to compensate for external inputs (e.g., synthetic fertilizers, synthetic pesticides, machinery, etc.) by using locally available natural resources more efficiently (Lee 2005). Their benefits include soil enhancement (particularly through the management of organic matter and soil biotic activity), crop and environment protection (mainly through diversification of species and genetic resources), and the management of biological interactions. Based on these features, these SAPs do not compromise either productivity or environmental health. However, they require improved use of farm management practices (Lee 2005). This is needed since their application is complex. For instance, intercropping and crop rotation involve a range of management decisions: choosing particular crop species from an array of alternatives; evaluating their relative agronomic and economic advantages; deciding the optimum combinations and rotations of crop species; planning both the timing and the use of labor inputs; and modifying marketing strategies. Other SAPs are similarly knowledge, skill, and labor demanding.

Data

To understand the adoption of the six SAPs, a survey was conducted between October 2011 and March 2012. Using a random method, the sampling relied on a list (sampling frame) of farms that were registered with the Departments of Agriculture Malaysia, Sabah, and Sarawak. Respondents were then selected based on a filtering criterion: they must be the main farm decision maker. A total of 1,168 randomly selected vegetable farmers were interviewed, representing about 86 % of the response rate.

The survey data were collected through the use of a structured questionnaire designed according to the conceptual framework (see Fig. 1). The questionnaire was developed through a literature review, followed by focus group interviews. While the former helped to identify common factors that were to be included in the questionnaire, the latter aimed to both check their relevance to our study area and elicit techniques for survey operation (for details, see Tey et al. 2012a, b). Overall, the focus group interviews reaffirmed our proposed factors, with a slight modification to use simpler terms in some cases. Among suggested survey techniques, visuals proved to be an ideal way to help farmers understand individual SAPs.

The dataset (see Table 1) shows that the adoption rates varied across the six selected SAPs. High adoption rates were recorded for organic fertilizers/composts (85 %), conservation tillage (83 %), and crop rotation (77 %). According to respondents, this is because those SAPs are the fundamental to vegetable production. Moderate adoption rates were indicated for intercropping (55 %) and cover crops/mulches (47 %), and a low adoption rate for

Table 1 Descriptive statistics of variables ($n = 1{,}168$)

Variables and units	Mean	Standard deviation	Cronbach's alpha
Dependent variables			
Conservation tillage (0/1)	0.835[a]	0.372	–
Intercropping (0/1)	0.548[a]	0.498	–
Cover crops/mulches (0/1)	0.471[a]	0.499	–
Crop rotation (0/1)	0.766[a]	0.424	–
Organic fertilizers/composts (0/1)	0.850[a]	0.357	–
Integrated pest management (0/1)	0.086[a]	0.281	–
Socio-economic factors			
Male (0/1)	0.680[a]	0.467	–
Age (years)	49.739	13.495	–
Chinese (0/1)	0.161[a]	0.368	–
Formal education (years)	7.884	4.357	–
Farming experience (years)	16.530	13.591	–
Household size (persons)	6.470	3.642	–
Number of full-time laborers (persons)	2.659	5.209	–
On-farm working hours (per week)	38.290	18.826	–
Financial capital (RM)	78,210	230,914	–
Keep livestock on farm (0/1)	0.166[a]	0.373	–
Off-farm employment (0/1)	0.274[a]	0.446	–
Married (0/1)	0.896[a]	0.306	–
Access to finance (0/1)	0.272[a]	0.445	–
Farm size (hectares)	4.438	10.323	–
Agro-ecological factors			
Flat land (0/1)	0.918[a]	0.275	–
Lowlands (0/1)	0.846[a]	0.361	–
Presence of environmental issue (0/1)	0.137[a]	0.343	–
Duration of land used for farming (years)	13.381	14.409	–
Practice organic farming (0/1)	0.393[a]	0.489	–
Southern region (0/1)	0.129[a]	0.336	–
Central region (0/1)	0.157[a]	0.364	–
Northern region (0/1)	0.239[a]	0.427	–
Eastern region (0/1)	0.164[a]	0.371	–
Land ownership (0/1)	0.544[a]	0.498	–
Institutional factors			
Organizational membership (0/1)	0.408[a]	0.492	–
Participation in a certification program (0/1)	0.068[a]	0.251	–
Participation in an institutional arrangement (0/1)	0.637[a]	0.481	–
Informational factor			
Usefulness of information (1–7 agreement levels)	4.512	0.982	–
Perceived attributes			
Relative advantage (1–7 agreement levels)[b]	5.775	0.816	0.873
Compatibility (1–7 agreement levels)[b]	5.330	0.968	0.863
Complexity (1–7 agreement levels)[b]	2.670	1.183	0.890
Trialability (1–7 agreement levels)[b]	5.203	1.066	0.848
Psychological factors			
Intention to adopt or continue using (1–7 agreement levels)[b]	5.462	1.199	0.957
Habit (1–7 agreement levels)[b]	4.741	1.325	0.809

Source survey sample in the Malaysian vegetable production sector, 2011–2012

[a] The estimate is interpreted as a percentage in relation to those who answered "Yes = 1"

[b] Average point of multiple items was calculated. Their internal consistency was attained according to the values of Cronbach's alpha

Table 2 Standardized and unstandardized logistic regression coefficients of the adoption of sustainable agricultural practices

	Conservation tillage		Intercropping		Cover crop/mulches		Crop rotation		Organic fertilizers/composts		Integrated pest management	
	SC	UC	SC	UC	SC	UC	SC	UC	SC	UC	SC	UC
Intercept		−0.217		−3.642***		−2.469*		−1.722		0.742		−4.325
Socio-economic factors												
Male	−0.144	−0.197	*−0.199*	*−0.566***	0.138	0.425*	−0.115	−0.211	0.315	0.382	1.555	1.293**
Age	0.060	0.003	−0.027	−0.003	0.058	0.006	−0.042	−0.003	−0.305	−0.013	−0.203	−0.006
Chinese	*0.858*	*1.499***	0.150	0.541	0.133	0.518	0.122	0.285	−0.269	−0.415	*2.035*	*2.149****
Formal education	−0.160	−0.024	−0.014	−0.004	*0.219*	*0.072****	0.278	0.055*	−0.167	−0.022	0.450	0.040
Farming experience	−0.415	−0.020	0.071	0.007	0.003	0.000	0.191	0.012	0.013	0.001	−0.858	−0.025
Household size	−0.073	−0.013	−0.005	−0.002	0.009	0.003	0.196	0.046	0.056	0.009	−0.626	−0.067
Number of full-time laborers	*−0.925*	*−0.114***	−0.088	−0.022	−0.083	−0.023	*−0.567*	*−0.093**	−0.302	−0.033	0.274	0.020
On-farm working hours	0.280	0.010	−0.125	−0.009	0.006	0.000	0.040	0.002	−0.085	−0.003	0.025	0.001
Financial capital	*0.854*	*0.001**	0.057	0.001	0.105	0.001	*1.184*	*0.001****	*1.655*	*0.001**	−0.525	0.001
Keep livestock on farm	0.304	0.524	0.063	0.224	*0.152*	*0.586***	−0.060	−0.139	−0.179	−0.272	0.812	0.845
Off-farm employment	0.247	0.356	0.073	0.216	0.005	0.016	0.013	0.026	0.040	0.051	−0.617	−0.536
Married	−0.008	−0.016	0.095	0.411	−0.110	−0.516	0.141	0.396	0.288	0.533	−0.335	−0.425
Access to finance	0.500	0.721*	0.099	0.294	0.087	0.281	0.161	0.310	0.577	0.734*	0.426	0.371
Farm size	0.788	0.049	0.026	0.003	0.092	0.013	0.303	0.025	0.103	0.006	0.204	0.008
Agro-ecological factors												
Flat land	−0.299	−0.698	−0.110	−0.532	−0.068	−0.354	*−0.337*	*−1.050**	−0.142	−0.293	*−2.066*	*−2.913****
Lowlands	0.047	0.083	0.022	0.080	*−0.209*	*−0.833****	−0.096	−0.228	0.166	0.260	−0.160	−0.172
Presence of environmental issue	−0.013	−0.024	0.015	0.058	0.027	0.113	0.327	0.817	−0.150	−0.247	−0.323	−0.365
Duration of land used for farming	−0.426	−0.019	0.186	0.017*	0.060	0.006	0.220	0.013	0.228	0.009	−0.085	−0.002
Practice organic farming	0.469	0.616**	0.034	0.093	0.030	0.089	0.115	0.203	0.132	0.153	−0.045	−0.036
Southern region	−0.266	−0.509	*0.480*	*1.894****	*−0.227*	*−0.969****	*0.292*	*0.745**	0.319	0.539	*2.256*	*2.608****
Central region	0.005	0.009	*0.347*	*1.265****	−0.129	−0.509*	−0.027	−0.064	0.048	0.075	−0.158	−0.168
Northern region	0.772	1.161**	*0.273*	*0.846****	−0.043	−0.144	0.198	0.398	*1.031*	*1.369***	−0.479	−0.436
East coast region	*1.393*	*2.411****	*0.286*	*1.022****	0.159	0.614**	−0.258	−0.597*	0.185	0.283	*−1.940*	*−2.031***
Land ownership	0.160	0.206	−0.037	−0.098	0.106	0.305	0.013	0.022	−0.195	−0.222	−0.181	−0.141
Institutional factors												
Organizational member	0.609	0.795**	−0.028	−0.075	0.148	0.431**	−0.089	−0.156	*0.655*	*0.755***	−0.443	−0.350
Participation in a certification program	0.421	1.075	0.039	0.207	−0.136	−0.779*	0.082	0.281	−0.023	−0.053	1.255	1.939***
Institutional participation	−0.429	−0.572*	−0.072	−0.197	0.067	0.200	−0.121	−0.215	*−0.741*	*−0.872***	−0.666	−0.537
Informational factor												
Usefulness of information	0.701	0.458***	*0.374*	*0.505****	0.076	0.111	0.200	0.174	0.043	0.025	*1.679*	*0.664****
Psychological factors												
Intention to adopt or continue using	0.643	0.344**	0.017	0.019	0.095	0.114	−0.297	−0.212	0.465	0.220	*1.849*	*0.598***
Habit	−0.264	−0.128	−0.081	−0.081	*0.163*	*0.177**	−0.027	−0.018	0.516	0.221*	1.488	0.436*

Table 2 continued

	Conservation tillage		Intercropping		Cover crop/mulches		Crop rotation		Organic fertilizers/composts		Integrated pest management	
	SC	UC	SC	UC	SC	UC	SC	UC	SC	UC	SC	UC
Perceived attributes												
Relative advantage	*−0.748*	−0.589**	0.078	0.127	−0.006	−0.010	*0.363*	*0.381**	*−0.650*	*−0.451**	−0.912	−0.434
Compatibility	0.658	0.436**	0.164	0.224	0.009	0.014	0.098	0.087	0.408	0.239	−0.695	−0.278
Complexity	0.120	0.065	−0.067	−0.075	0.084	0.102	0.297	0.215	0.082	0.039	−1.283	−0.421*
Trialability	−0.151	−0.091	−0.017	−0.022	−0.063	−0.085	0.022	0.018	0.060	0.032	0.253	0.092
Chi-square	120 ($p < 0.000$)		128 ($p < 0.000$)		104 ($p < 0.000$)		76 ($p < 0.000$)		50 ($p < 0.05$)		132 ($p < 0.000$)	
−2 Log likelihood	409.1		716.1		744.9		558.5		381.6		241.2	
Cox and Snell R^2	0.178		0.188		0.155		0.117		0.078		0.194	
Nagelkerke R^2	0.308		0.252		0.208		0.181		0.156		0.450	
Average correct prediction (%)	86.7		68.7		67.5		80.4		88.9		93.7	

SC standardized coefficient, *UC* unstandardized coefficient

* 10 % significance level

** 5 % significance level

*** 1 % significance level

IPM (9 %). Given these variations, it was interesting to check whether there exists a pattern in the effect of independent variables, which were commonly investigated by past studies and discussed in "Literature review".

Findings

The independent variables were initially checked for multicollinearity using the SPSS procedure of "collinearity diagnostics". No evidence was found for multicollinearity.

A logistic regression was estimated for the individual SAPs. The results (see Table 2) show an acceptable model fit: (1) Chi-square measures indicate that the increase in model fit (compared with the intercept-variable model) was statistically significant; (2) the −2 log likelihood ranges from 241 to 745; (3) the Cox and Snell R^2 values span between 0.078 and 0.188; (4) the Nagelkerke R^2 values vary from 0.16 to 0.45; and (5) correct prediction of adoptive decisions ranges from 68 to 94 %.

In Table 2, attention is paid to the SC of statistically significant factors. They were calculated to provide a standard to indicate their relative importance by comparing their (absolute) magnitude within a regression. In the adoption of crop rotation, as an example, financial capital (1.18)[1] was the most important factor. It means that, for each standard deviation increase in the independent variable, adoption would, on average, increase by 1.18 standard deviations. Within the regression, the other relatively important factors are as follows: number of full-time laborers (−0.57), relative advantage (0.36), flat land (−0.34), and geographical location (0.29).

To have a clear picture, statistically non-significant factors are not discussed and the top five important factors (among the statistically significant factors) were italicized in each regression. The italicized factors demonstrate that the relative importance of statistically significant factors is heterogeneous across SAPs. Notwithstanding that, they can be broadly discussed according to the six dimensions: socio-economy, agro-ecology, institutional, information, perceived attributes, and psychology.

Socio-economic factors

The dummy variable for male was one of the top five factors in the intercropping (−0.20) model and, to a lesser extent and in a different direction, in the cover crops/mulches and IPM models. The mixed findings of such

[1] Though standardized coefficients usually range between ±1, they are not always so (Keith 2006). When found to be above 1, there is a need to check for multicollinearity (Menard 2011). As noted earlier, multicollinearity did not exist among the independent variables.

relationships do not lend themselves to easy explanation. Notwithstanding that, its negative relationship with the adoption of intercropping suggests that Malaysian female farmers may not face socio-cultural restrictions as much as those in other developing countries.

The dummy variable for Chinese vegetable growers was highly influential in the cases of conservation tillage (0.86) and IPM (2.04). These findings imply that Chinese farmers are more likely than other ethnics to be adopters of these SAPs. This is borne out by Barrow et al. (2010), who observed greater adoption among Chinese farmers for maintaining environmental quality. Against other ethnics, the difference could be due to dissimilarity in social and religious values in relation to resource management.

Years of education were relatively important in cover crops/mulches (0.22) regression and, to a lesser extent, in crop rotation. These findings indicate that higher education levels increase the odds of adopting these SAPs. This might be because risk evaluation and application of these SAPs is knowledge based. Hence, higher educated farmers are more willing to take "reasonable" risks and accept operation alterations.

The number of full-time laborers was one of the most important factors in relation to conservation tillage (−0.93) and crop rotation (−0.57). Contrary to D'Emden et al. (2008), this factor had a negative impact on adoption. This finding could be explained by the shortage of farm labor in Malaysia. Foreign labor is imported at a substantial cost and hired for a limited period. Renewal of employment visas is rare; recruitment and training incur additional costs and risks to farm enterprises. Under these pressures, labor is more often assigned to effective production activities.

Financial capital was a major factor with regard to conservation tillage (0.85), crop rotation (1.18), and organic fertilizers/composts (1.66). In particular, this factor ranked first in crop rotation and organic fertilizers/composts. Its positive association with respective dependent variables suggests that greater financial capital makes their adoption more feasible. These SAPs have a conservation feature and the findings are consistent with Pampel and van Es (1977), who have examined conservation practices. A partial explanation might be attributed to the associated costs of SAPs (e.g., organic fertilizers/composts). The rest might be related to the nature of SAPs that do not offer immediate/tangible benefits. Farmers with greater financial capital, therefore, have a stronger financial capacity for investment and handling uncertainties in the identified SAPs.

Keeping livestock on the farm was another reasonably influential factor leading to the adoption of cover crops/mulches (0.152). In Malaysia, livestock is rarely used for vegetable production. Rather, it is kept mainly for earning additional farm income. While waiting for its marketability, its wastes are composted. They are often applied as a form of mulch to the soil surface.

Access to finance was statistically significant in conservation tillage and organic fertilizers/composts. Credit and loans act as alternative financial sources for farm investment.

Agro-ecological factors

Flat land was (relatively) a main factor with regard to crop rotation (−0.34) and IPM (−2.07). They suggest that these SAPs are more likely to be seen on steeper plots. To deal with environmental threats, crop rotation is used to reduce soil erosion through an improvement in soil quality (Lockie et al. 1995). Such an explanation, however, does not apply to IPM. Rather, its adoption could be the result of a primary extension focus, for some decades, for IPM on steeper plots (Taylor et al. 1993).

Lowlands was a fairly important factor on the subject of cover crops/mulches (−0.21). Consistent with our expectations, farms in highlands have a higher probability of adoption. Because their sustainability is challenged by water run-off and soil erosion, cover crops/mulches are used to facilitate water retention and soil protection (Stoffella et al. 1997).

Geographical location was a dominant factor in all SAPs. East Malaysia (the eastern region) was used as the baseline comparison with those in Peninsular Malaysia (the Northern, Central, Southern, and East Coast regions). In general, respondents in Peninsular Malaysia were more likely than those in the eastern region to adopt SAPs. A number of exceptions were found: in the southern and central regions in cover crops/mulches and in the eastern region in crop rotation and IPM. On average, despite the slight contradiction, the findings point to the resource difference between Peninsular Malaysia and East Malaysia. The resource may refer to land availability, which is limited in the former but still plentiful in the latter. This argument is supported by a number of local studies (e.g., Hansen and Mertz 2006; Cramb 1989, 1993) which observed, over decades, the practice of shifting cultivation activities in East Malaysia. Because of shorter farming horizons, farmers in East Malaysia are less inclined to adopt SAPs.

The longer the duration that lands have been used for farming produced a higher probability that intercropping would be adopted. Organic farms had a statistically significant positive association with the adoption of conservation tillage.

Institutional factors

Organizational membership was a comparatively important factor pertaining to organic fertilizers/composts (0.66) and, to a lower degree, in conservation tillage and cover crops/

mulches. Supported by Kassie et al. (2009), their positive signs suggest that members of farmers' associations and/or cooperatives have greater odds of becoming adopters. Information shared by members is generally useful and practical, including "dos and don'ts" vis-à-vis pros and cons of a practice. Moreover, members know each other and speak the same language as Malaysian rural organizations and are largely location- and ethnically based.

Participation in an institutional arrangement was a relatively main factor on the subject of organic fertilizers/composts (−0.74) and, to a lesser extent, in conservation tillage. This suggests that participants are unlikely to be adopters of these SAPs. The rationale for this finding might lie with the motivations or pressures that arise from participating in such an arrangement. Taking contract farming as an example, farm enterprises enter contracts upon consideration of the transaction costs and, therefore, the expected profit (Key and Runsten 1999). Both economic benefits pay off only when an amount of produce is delivered timely. Under this pressure, participants may tend to sacrifice long-term sustainability by preferring conventional practices (synthetic fertilizers and pesticides in our case) as an immediate guarantee of positive results.

Another statistically significant institutional factor was participation in a certification program in respect to cover crops/mulches and IPM. It should be noted that the sign of participation in a certification program was different between cover crops/mulches and IPM. The difference might be attributed to the requirements of certification programs (e.g., Good or Organic Agricultural Practices): pesticide control is stipulated but cover crops/mulches remain optional. Moreover, the latter increases production costs. The compounding effect results in cover crops/mulches being less likely to be adopted.

Informational factor

The usefulness of information was one of the key factors in respect to intercropping (0.37) and IPM (1.68) and, to a minor level, in conservation tillage. This factor underscores an implication that, not only access to information is essential, but its usefulness is also critical. Similar findings have also been advanced by Robertson et al. (2012) and Larson et al. (2008) in other sustainable practice studies. A slight difference, however, occurs, since these SAPs are more knowledge-intensive than input-based technologies. Intercropping requires information on how two or more crops can be mixed and matched to produce an optimal return. IPM application depends on knowledge principles in respect to the local environment (as to what, how much, and when to apply) (Taylor et al. 1993). The use of conservation tillage is also complex, since there is no single solution that exists for all soil management issues (Dauphin 2000).

Psychological factors

Intention to use or to continue using was a major factor in IPM (1.85) and, to a lower level, in conservation tillage. Its positive influence on the adoption likelihood of these SAPs is reinforced by Calkins and Thant (2011), who evidenced that sustainable behavior emerges from stronger intentionality. This applies especially to current adopters. To reap the long-term benefits of SAPs, they exhibit a greater intention to maintain these practices.

Habit was a relatively key factor in the area of cover crops/mulches (0.16) and, to a lesser extent, in organic fertilizers/composts and IPM. This sign is consistent with our expectation. When SAPs have been used, a routine is established. Moreover, habit always results in familiarity and an interest towards continuity in farming activities (Jaza Folefack 2005).

Perceived attributes

Relative advantage was a primary factor with respect to conservation tillage (−0.75), organic fertilizers/composts (−0.65), and crop rotation (0.36). Contrary to our expectation, mixed signs were obtained. No explanation, however, is available in the literature. Notwithstanding that, the findings might be explained from the mean statistics (Table 1) of these SAPs and the attribute. Firstly, adoption rates for conservation tillage (84 %) and organic fertilizers/composts (85 %) were higher than those for crop rotation (77 %). Secondly, the mean statistic of relative advantage was 5.775, which suggests that respondent perception towards this attribute was moderately rather than extremely positive. Recalling that, what matters is the *degree* of perception. When putting the adoption rates and the degree of perception together in the picture, it is not, therefore, surprising to get mixed directions in respect to the relationship between them.

Other statistically significant perceived attributes were "compatibility" in conservation tillage and "complexity" in IPM. Their signs are as expected.

Conclusions and policy implications

Adoption rates of SAPs are low in many countries. This study has made two contributions in obtaining a refined understanding of adoption. First, a set of multidimensional factors that are common in the literature has been investigated. The strength of such a multidimensional investigation is in its ability to offer insights from different perspectives. Secondly, SCs have been estimated to identify the relative importance of statistically significant factors. The value of such a prioritization exercise is as a guide to point out which statistically significant factors should be emphasized.

Using survey data from Malaysian vegetable farmers, the findings have suggested that the adoption of SAPs generally depends upon a range of socio-economic, agro-ecological, institutional, informational, and psychological factors, as well as perceived attributes. This supports the extrapolation of multidimensionality in adoptive decisions made by review studies (e.g., Knowler and Bradshaw 2007; Tey and Brindal 2012). No single dimension can offer the best explanation. Therefore, policymaking should fundamentally be based on a multidisciplinary understanding of the issue (Tey et al. 2012c).

General policy implications can be garnered from the relative importance of statistically significant factors across the selected SAPs. These are made possible by identifying the commonality of their five most influential factors (see Table 3).

Policy focus should be on differences in land availability between geographic locations. Pressures in respect to land scarcity often push farmers towards sustaining currently available land. Nevertheless, this does not necessarily mean restricting access to land in "land-rich" areas. Rather, indirect pressures (e.g., sustainability assessment and a penalty to discourage degradation before "exiting" land) could be used to inculcate a sense of responsibility within farmers. We believe this to be our most important finding in respect to its implications for government policy.

Policy emphasis could be placed on mechanisms which recognize the importance of financial capital in enabling investment in and the buffer management of SAPs, especially when the benefits are long term. Raising financial capital is challenging given limited farm assets. Options to overcome financing problems may include direct finance (e.g., incentive), indirect finance (e.g., zero-interest loans), and/or a safety net.

Additionally, policy attention should be devoted to a number of factors, including the workforce size, the usefulness of information, Chinese ethnicity, and relative advantage. The implications are that policies to improve adoption rates could include, for example, granting longer working visas to foreign laborers; involving farmers in information generation for campaign design; promoting the sustainability culture found in the Chinese to other ethnic groups; and relating the non-economic benefits of SAPs to profitability (Tey et al. 2013).

Alternatively, policymaking in respect to a specific SAP can be guided by the relative importance of statistically significant factors. Such effort is crucial when the SAP is either essential, desirable, or the least adopted. To further promote the least adopted IPM, for example, our findings render some useful cues on targeting the "more likely" adopters. Future campaigns should target, in order of significance, the southern region, the highlands, and Chinese farmers. Any campaign, at the same time, should be designed to target the modification of intention, through the delivery of more relevant and useful information on SAPs.

By prioritizing statistically significant factors, this case study has demonstrated a statistical method to refine our understanding of the adoption of SAPs. Importantly, this method can be extended to investigate similar issues (e.g., adaptation to climate change) in other countries and regions. Its application will generate clearer guidelines for policymaking in relevant areas. According to Pretty (1995), resultant policies which cater for the particular conditions of individual locales should prove highly influential in modifying farmer behavior. The creation of policies which resonate with farmers will, in turn, enhance the adoption of SAPs.

Table 3 Top five factors influencing the adoption of sustainable agricultural practices

Sustainable agricultural practices	Ranking				
	1	2	3	4	5
Conservation tillage	Geographical locations	Number of full-time laborers	Chinese	Financial capital	Relative advantage
Intercropping	Geographical locations	Usefulness of information	Male	Duration of land used for farming	
Cover crops/mulches	Geographical locations	Years of formal education	Lowlands	Habit	Keep livestock on farm
Crop rotation	Financial capital	Number of full-time laborers	Flat land	Relative advantage	Geographical locations
Organic fertilizers/composts	Financial capital	Geographical locations	Participation in an institutional arrangement	Organizational membership	Relative advantage
Integrated pest management	Geographical locations	Lowlands	Chinese	Intention	Usefulness of information

Source extracted from the estimates of standardized logistic regression coefficients in Table 2

A limitation of this study is in the reflection of our focus on the "more likely" adopter groups. Though our results provide valuable information for effective promotion for such targets, this study does not offer insights into suitable approaches for "less likely" adopter groups. Such information is equally important if sustainable agriculture is to be realized on a large scale. It seems likely that different strategies will have to be tailored to the "less likely" adopter groups. Future research should aim to provide empirical information across both the "more likely" and "less likely" adopter groups in the hope that it might result in better guides for promoting sustainable agriculture.

Acknowledgments This paper is part of a PhD research project at the University of Adelaide. The realization of the project is made possible by Adelaide Scholarships International (ASI) from the University of Adelaide to Yeong Sheng Tey. The research project is also partly funded by the Universiti Putra Malaysia's Research University Grant Scheme (Vot 9199741). We thank the three anonymous reviewers for their comments concerning ways to improve the quality of the manuscript, and Keith Barrie for proofreading an earlier version of this paper.

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