World Development Perspectives 18 (2020) 100204

Contents lists available at ScienceDirect

World Development Perspectives

journal homepage: www.elsevier.com/locate/wdp

When climate change is not psychologically distant – Factors influencing the acceptance of sustainable farming practices in the Mekong river Delta of Vietnam

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ARTICLE INFO

Keywords:
Rice straw
Vietnam
Decision making
Risk perception
Acceptance
Climate change

ABSTRACT

Rice farmers in the Mekong Delta are not only experiencing challenges due to climate change but are also expected to increase production through sustainable intensification. Increased production and mechanization, such as using combine harvesters leave farmers with more rice straw in the field, which farmers often choose to burn resulting in adverse health effects, increased air pollution and increased greenhouse gas emissions. Farmer adoption of recently promoted sustainable rice straw management practices is low. The present study, therefore, investigated factors influencing the acceptance of different rice straw management practices. 111 smallholder rice farmers participated in the study. Farmers' perceptions of risks, benefits and their acceptance of eight different rice straw management practices including burning, soil incorporation, composting, mushroom and biogas production, and different collection methods, was investigated via a survey questionnaire. Results show that farmers often burn their rice straw even though they perceive high risks, few benefits and expressed low levels of acceptance for rice straw burning. Acceptance of rice straw management practices differs between practices; however, benefit perceptions are the strongest predictor for all practices followed by knowledge about climate change. Risk perceptions were a weak predictor for some practices including burning and biogas production. The regression models explain up to 50% of the variance. Results show that the experiential system determines farmers' perception of practiced straw management options. This study also shows that even though climate change is not psychologically distant to farmers, sustainable behavior will depend on the acceptability, feasibility and perceived benefit of options provided.

1. Introduction

Vietnam, like many other Asian countries, has been affected by global warming (Cullen & Anderson, 2017). Consequently, for Vietnamese rice farmers, climate change adaptation, mitigation, and transformation processes are important to secure livelihoods. Vietnam's vulnerability to climate change is due to its very long coastline and high dependence on agriculture especially in the Mekong Delta region (Cullen & Anderson, 2017). Furthermore, Vietnam is also affected by the tropical monsoon belt of South East Asia which can cause heavy rains and storms. In recent years the frequency of these tropical storms, such as typhoons, has increased considerably (see (Cullen & Anderson, 2017) for review). Meteorological observations have shown that there are extremes in the wet and dry season cycles which will have a disproportionate effect on rice yields, especially from the autumn paddy (Cullen & Anderson, 2017). Vietnam is one of the main rice-producing and rice exporting countries in South East Asia. In the last decades, rice production has continuously increased to almost 40 million tons, with an average yield of 5.3 t/ha (GRiSP, 2013). This increase resulted from the expansion of rice cropping areas, improved farming methods, and the number of crops grown per year (GRiSP, 2013; Kontgis, Schneider, & Ozdogan, 2015). This generally positive development does not take place without any compromises. Increasing the number of crops grown, results in a high amount of additional biomass not only in grain but also in rice straw. Managing the additional amounts of rice straw along with the stubble left in the field after harvest has become a major challenge. An easy and often practiced solution is burning the straw (Streets, Yarber, Woo, & Carmichael, 2003), which has not only adverse effects

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https://doi.org/10.1016/j.wdp.2020.100204
Received 26 June 2019; Received in revised form 4 March 2020; Accepted 16 April 2020
Available online 25 April 2020

on peoples' health but also increases emissions of environmental pollutants. Little is known, however, about farmers' acceptance of alternative rice straw management practices.

Rice cultivation is known to be responsible for over 10% of agricultural greenhouse gas (GHG) emissions and about 1.3% to 1.8% of the anthropogenic GHG emissions (Maraseni, Deo, Qu, Gentle, & Neupane, 2018). These GHG emissions contribute to global warming and climate change. Parts of these GHG emissions come from open-field burning of rice straw (Gadde, Bonnet, Menke, & Garivait, 2009) and residue left in the field (Maraseni et al., 2018; Romasanta et al., 2017). Vietnam produces over 24 million tons of harvested rice straw per year (Hong Van et al., 2014). Burning causes not only emissions of GHG but also loss of nitrogen, phosphorus and potassium from the soil (Mandal et al., 2004). Burning depletes the organic matter content of the soil, reduces beneficial soil bacteria and causes high levels of pollution (Mandal et al., 2004). However, it is also perceived as a good control mechanism for weeds and pests (Mandal et al., 2004).

Another traditional but potentially problematic management practice is straw incorporation into paddy soils. This straw management practice generally provides nutrients such as nitrogen, phosphorus, potassium, and silicate (Dobermann & Fairhurst, 2002; Ponnamperuma, 1984; Saothongnoi, Amkha, Inubushi, & Smakgahn, 2014). However, the incorporation of rice straw into soils not only enhances the production of toxic substances (Yoshida, 1981) but can cause a considerable increase of GHG emissions in the following rice season especially when the composting of the organic matter is incomplete (Wassmann et al., 2000; Yagi & Minami, 1990). The additional amount of organic matter is a favorable substrate for methanogenic archaea that decompose the straw in anaerobic soil conditions and produce methane (Cicerone & Oremland, 1988). Incomplete composting poses challenges especially in intensive systems with two or three seasons per year (Nguyen et al., 2020).

In recent years a variety of straw management practices have been introduced to prevent undesirable management practices such as rice straw burning or incomplete decomposition. These practices include a variety of straw collection technologies like straw balers (self-propelled or pulled by a tractor). These balers collect and compact rice straw in the field to then be used for other practices such as mushroom growing, biogas production, or for cattle feed and bedding. Each of these practices has its own advantages and disadvantages comprising purchase costs or machinery rental (Nguyen et al., 2020; Nguyen et al., 2016). GHG emissions vary between different practices. Among the in-field options, the highest emissions are associated with straw being incorporated into the soil with the lowest for burning (Romasanta et al., 2017). Among off-field options, high GHG emissions are generated from straw used as cattle feed because rice straw has a low digestibility and has a high fiber content (Holter & Young, 1992; Shibata, Terada, Iwasaki, Kurihara, & Nishida, 1992). Composting shows low GHG emissions and returns nutrients to the soil, thus increasing soil fertility (Nguyen et al., 2020). Biogas production can theoretically reduce GHG emissions if it replaces fossil fuels. However, small biogas plants often leak while large plants can have over-production of methane which might have to be released into the atmosphere (Vu, Vu, Jensen, Sommer, & Bruun, 2015). The implementation of sustainable straw management practices is, therefore, an important aspect of transforming rice value chains to reduce GHG emissions. However, sustainable straw management will only be possible if farmers change their current management practices.

Different factors have been shown to influence farmers' willingness to adopt sustainable farming practices. It has been shown that knowledge about climate change and the causes of climate change are important determinants of personal engagement to act and support climate protection policies (Bord, O'Connor, & Fisher, 2000). It has been shown that Vietnamese farmers were more likely to have an adaptation intention when they perceive higher risks of climate change, belief in climate change or when they are under pressure from other people to conduct adaptive measures (Dang, Li, Nuberg, & Bruwer, 2014a, 2014b). Furthermore, it has been shown that knowledge about the consequences of climate change was most strongly related to attitudes towards climate change (Tobler, Visschers, & Siegrist, 2012b). Consumer studies have shown that willingness to act or willingness to support climate policy measures depends on perceived costs, perceived climate benefit, and political affiliation (Tobler, Visschers, & Siegrist, 2012a). It has also been shown that moral foundations are drivers with respect to climate change action, in particular compassion, fairness and purity (Janis, Poppy, Robert, & Shorna, 2016). Other than that, personal experience (Broomell, Budescu, & Por, 2015; Spence, Poortinga, Butler, & Pidgeon, 2011; Spence, Poortinga, & Pidgeon, 2012) knowledge about climate change (Bord et al., 2000; Tobler et al., 2012b) as well as values, believes and world views (Bain, Hornsey, Bongiorno, & Jeffries, 2012) have been shown to be drivers for climate action. Reducing individuals' psychological distance to climate change and highlighting its proximal consequences have been suggested to increase sustainable behaviors (Spence et al., 2012). However, most of the studies have been conducted in developed countries with the general public or student populations. Consequently, limited knowledge exists about farmers' understanding, perceptions, and attitudes towards climate change and factors influencing their willingness to act. However, it has been shown that risk perception of climate change in smallholder farmers of developing countries determines the choice of adaptation measures (Apata, 2011; Belay, Recha, Woldeamanuel, & Morton, 2017). Other authors have investigated factors influencing smallholder farmers' climate change perceptions and found that farmers perceive multiple changes in climate (Habtemariam, Gandorfer, Kassa, & Heissenhuber, 2016; Lasco, Espaldon, & Habito, 2016). These perceptions may not always reflect the actual changes but it can be generally concluded that farmers are aware of climate change and experience, for example, rising temperatures and extreme weathers such as drought or heavy rains (Abid, Schilling, Scheffran, & Zulfiqar, 2016; Cullen & Anderson, 2017; Cullen, Anderson, Biscaye, & Reynolds, 2018). A study conducted in the Ivory Coast with rice farmers showed that factors such as the perceived occurrence of new pests and insects and support from national and international organizations were relevant to farmers' decisions to adapt to climate change (Comoe & Siegrist, 2015). However, technology acceptance and adoption has mostly been influenced by the perceived ease of use and by practical benefits or economic values (Davis, 1989). A study with Malaysian vegetable farmers concluded that adoption of new practices and technologies depended on a range of socio-economic, agro-ecological, institutional and psychological factors (Tey et al., 2014). A review of technology adoption by smallholder farmers in developing countries concluded that technological, economic, institutional, and human-specific factors determine agricultural technology adoption (Mwangi, Kariuki, & Egerton, 2015). A recent study in the Vietnamese Mekong Delta investigated the aforementioned factors and additionally included farmers' perception of risks associated with the new farming practice to investigate the adoption of eco-friendly rice cultivation practices (Tu, Can, Takahashi, Kopp, & Yabe, 2018). Results of that study show that membership in agricultural cooperatives or clubs, perception of biodiversity losses, perceived ease of technology use, farmer experience, and the perceived differences in selling price all had positive effects on adoption, whereas risk perception and the number of paddy plots negatively influenced the adoption of eco-friendly rice cultivation practices (Tu et al., 2018). Therefore, it can be assumed that perceptions of risks and consequently risk communication may be crucial for acceptance and adoption of the new agricultural technologies and practices.

1.1. Rationale of the study

Various rice straw management practices and technologies have been developed to handle the increasing amounts of rice straw effectively and in environmentally friendly ways to mitigate the negative effects of undesired straw management practices. Investigating farmers' risk perception of rice straw management practices may be crucial for making responsible policy decisions. In the last few decades, a number of studies investigated peoples' perception of various hazards and technologies. Often the 'psychometric paradigm' (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978) is cited as a landmark in research (Marris, Langford, Saunderson, & Oriordan, 1997) which in general investigates public attitudes towards risks. It has been shown that perception and consequently acceptance of technologies are often guided by perception of risk and benefits. The present study will apply the 'psychometric paradigm' to a cohort of Vietnamese rice farmers to investigate attitudes towards different rice straw management practices. Therefore, risk and benefit perceptions will be evaluated for a variety of rice straw management options. Research has demonstrated that risk perceptions are influenced by several factors such as the qualities of a hazard or technology, whether exposure to it is voluntary and/ or controllable, whether its adverse consequences can be catastrophic, whether its benefits are distributed fairly among those who bear the risks, who is exposed to the risks and who will receive the benefits (Slovic, 1987). Therefore, the present study will investigate perceived risks and benefits for different agents: the farmers themselves, society and the environment. Hypothesizing that either risk or benefit perceptions or both determine acceptance of straw management practices it is important for risk communication and policy governance to determine which factors influence farmer's perceptions and attitudes towards those practices. It has been shown that when people construct risk perceptions, they also use heuristics and employ a variety of individual biases, for example, relying on trust when knowledge about a technology is limited (Siegrist, Cvetkovich, & Roth, 2000). Another heuristic often applied is the affect heuristic, which highlights the importance of affect in risk perception (Finucane, Alhakami, Slovic, & Johnson, 2000) which will be investigated in the present study to address the existing research gaps.

2. Methods

2.1. Questionnaire

A survey questionnaire was created using CommCare (Dimagi) a widely used data collection platform, predominantly for monitoring health information in developing countries (Agarwal et al., 2016). The survey started with an informed consent where participants were introduced to the study. Participants were free to withdraw from the study at any time without penalty and all data were kept strictly anonymous. No names or addresses of the farmers were recorded. Table 1

After the introduction, demographic characteristics such as age, gender, and education were recorded along with farm characteristics such as acres of farming land, the number of crops per year, and cropping patterns. Farmers were then asked to answer a set of knowledge questions concerning climate change. In total six items were used to measure farmers' knowledge about climate change (Table 3). Items were selected from a study on consumers' knowledge about climate change (Tobler et al., 2012b). Items included in the present study aimed to measure physical knowledge about CO_2 and the greenhouse effect (3 items) and knowledge concerning the expected consequences of climate change (3 items). Participants were asked to indicate for each statement whether they believed the statement to be true, false, or whether they did not know. The 'I don't know' option was included to avoid participants guessing (Tobler et al., 2012b). Three statements were correctly formulated and three statements were incorrectly formulated.

Farmers' perception of rice straw burning was evaluated using five statements (Table 2). These statements were evaluated on a six-point Likert-type scale ranging from 1 = completely disagree to 6 = fully agree. Farmers were also asked how much support they would expect from certain institutions including government, other farmers, universities, private companies, research institutions, and NGOs. The original question, however, was meant to identify participants' level of trust in these institutions, yet due to Vietnam's social and political structure, it was not possible to ask a trust-related question. In the following section, farmers were asked to read the fact sheets. In total eight rice straw practices were shown to the farmers (Table 1). Farmers were given time to read each fact sheet and were then asked a set of questions immediately after each fact sheet. Firstly, they were asked if they knew about the rice straw management practice, afterwards farmers who were aware of the management practice were asked if they have used this practice. For each fact sheet benefits, risks and acceptance of each rice straw management practice were evaluated on a six-point Likert-type scale ranging from 1 = not beneficial/no risks/no acceptance at all to 6 = very beneficial/ very high risks/very high acceptance. Each construct (benefit, risk, acceptance) was asked separately for farmers, for the society, and for the environment (e.g. 1. How beneficial do you think is biogas production from rice straw for the farmer? 2. How beneficial do you think is biogas production from rice straw for the society? 3. How beneficial do you think is biogas production from rice straw for the environment?). At the end, participants were asked how likely they would be to use the practice during the winter–spring, summer, and autumn–winter cropping season.

All questions and items were translated into Vietnamese and independently back-translated into English to ensure content validity.

2.2. Rice straw management fact sheets

All fact sheets had the same format and started with a short introduction of the management practice e.g. Biogas production/anaerobic digestion technology: 'Degrade and convert waste organic material into biogas, which can be utilized as a clean fuel for heat and power generation.' After this short explanation, a colored picture of the management practice followed. The second half of the fact sheet showed the characteristics of the straw management practice in bullet point format (Fig. 1). We included investment costs where necessary, the functionality of the practice, necessary supplements (e.g. animal manure for biogas production), benefits of the practice including profits where profit-generating, and greenhouse gas emissions as a verbal statement (e.g. biogas production: Zero emissions if system is managed properly). In total 12 fact sheets were created. All fact sheets were developed with a team of rice straw management professionals. All fact sheets were translated into Vietnamese and back-translated into English to ensure content validity.

2.3. Recruitment and data collection

The survey was conducted in three provinces of Mekong Delta – An Giang, Can Tho and Tien Giang from 18th to 24th of June 2018. Provinces were not randomly selected. Data were collected using Samsung Galaxy Tab A 7.0 (2016) LTE SM-T285. Farmers were purposely selected from 8 communes throughout the three provinces; An Giang, Can Tho, Tien Giang (Fig. 2). Local extension staff from each commune personally contacted the farmers and invited those who were willing to participate. Extension staff was asked to recruit about 40 farmers per province. The selection of farmers was based on local extension staff's network of farmers who proactively participated in commune-level farming activities such as training facilitated by the extension staff. All farmers are part of projects implementing the national policy "One Must Do, Five Reductions", which promotes best management practices in lowland rice cultivation. The focus of "One Must Do, Five Reductions" is to use high-quality seeds (One Must Do) and to reduce seed rates, pesticide use, fertilizer inputs, water use and postharvest losses (Stuart et al., 2018). Farmers were selected from existing project lists in collaboration with the local extension staff. In each commune, a central survey location was organized to gather the farmers for data collection.

Table 1
Rice straw management options and the associated explanation of the practice as appeared on the fact sheets.

Rice straw management option	Explanation
Rice straw incorporation	In manual harvesting options, only a small proportion of the total proportion of crop residue is often incorporated but where combine harvesting is conducted, unless baling is done, the total straw biomass will be incorporated into the soil during land preparation.
Rice straw burning	Open-field burning of straw is a quick, simple, and affordable method of reducing biomass quantities in the field.
Rice straw composting	Rice straw left in the field after harvest is collected and mixed with animal manure and allowed to degrade in the field by composting. A compost turning machine is used to improve decomposition and enhance the quality of compost.
Rice straw compacting	Rice straw compacting can be used to reduce the volume of rice straw and then minimize the transportation costs.
Biogas production from rice straw	Degrade and convert waste organic material into biogas, which can be utilized as a clean fuel for heat and power generation.
Urea treated rice straw – big dairy farm and silage bag (household scale)*	Rice straw has too few nutrients to be used as the only source of food for cattle but can be treated to increase the supply of energy and protein. In general, the daily maximum intake of rice straw by ruminants is about 1.0 – 1.2 kg per 100 kg of live weight.
Rice straw collection	
Self-propelled baler	This machine both makes and transports bales to the bund. Though it has higher capacity than roller baler, its collection capacity is lower as it moves on rubber chain wheels that allow it to be used on wet fields.
Roller baler	This kind of baler collects and compacts rice straw into round bales, which are left in the field. Therefore, this baler is not suitable to operate in wet fields.
Loose straw collection	Loose straw collection machines can be used to collect scattered straw on the field. This machine is usually self-propelled and is easy to operate.
Mushroom production (indoor and outdoor)*	Rice straw mushroom, *Volvariella volvacea*, is considered to be one of the easiest mushrooms to cultivate because of its short incubation period of 14 days. This tropical species thrives best at 30° − 35 °C for mycelia development and 28° − 30 °C for fruiting body production.

Note: * one fact sheet per option was created. The order in the table represents the order presented in the questionnaire.

Before the survey implementation, 10 senior students specializing in Plant Protection from the Faculty of Agriculture and Natural Resources from An Giang University were trained as enumerators to collect the data. The students were taught how to navigate the CommCare app and how to properly deliver the interview to farmers. The enumerators read the questions to the farmers whilst showing the tablet to the farmers. Enumerators inserted the answers from participants and navigated through the app.

2.4. Data analysis

Data were exported from the CommCare app into IBM SPSS Statistics 25. Descriptive statistics were used to provide a sample description. To investigate differences in count data χ^2 statistics were employed. Reliability of knowledge questions was analyzed using Cronbach's alpha. Furthermore, exploratory factor analysis with principal components as extraction method was used to investigate the underlying structure of the knowledge questions; Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity are presented. Mean differences were analyzed using *t*-test statistics, all multiple comparisons are Bonferroni corrected, or Analysis of Variance (ANOVA), effect sizes were calculated using means and standard deviations and are presented as Cohen's d. Furthermore, multiple regression models using the enter method were employed to investigate the factors influencing the acceptance of rice straw management practices.

3. Results

3.1. Participants

In total 111 participants took part in the study; 101 were male and 10 were female. The mean age was 51.9 (SD = 12.1) years old (minimum age was 27 years and the maximum was 73 years old). There was almost an even split between the three provinces, 38 farmers came from An Giang of which 17 farmers belong to a cooperative; 35 farmers came from Can Tho with 10 belonging to a cooperative, and 38 farmers came from Tien Giang of which 18 belonged to a cooperative. Most participants (43%) indicated secondary school as their highest level of education, followed by primary school (31%) and high school (23%). Three percent of the participants had a University degree and only one person reported to have had no schooling at all. On average, farmers had 1.07 (SD = 0.90) ha of farmland. Most farmers (n = 89) only practiced rice farming, of the other 22 farmers, 3 farmers practiced rice and fish farming, 3 farmers practiced rice and other cereal farming, and the other 16 farmers grew vegetables, fruits, and spices. Furthermore, 97.8% of the rice farmers reported growing 3 crops per year.

Table 2
Knowledge items used for the present study, response distribution and factor loadings.

				component	
	true	false	I don't know	1	2
Burning oil, among other things, produces carbon dioxide. ✓	45	20	46	0.282	**0.542**
Carbon dioxide is harmful to plants.	57	19	35	0.195	**0.732**
At the same quantity, carbon dioxide is more harmful to the climate than methane.	33	27	51	−0.005	**0.860**
For the next decades, the majority of climate scientists expect a warmer climate that increases the melting of polar ice, which will lead to an overall rise of the sea level. ✓	85	2	24	**0.748**	0.043
For the next decades, the majority of climate scientists expect an increase in extreme events, such as droughts, floods and storms. ✓	100	1	10	**0.817**	0.250
For the next decades, the majority of climate scientists expect a warmer climate to increase water evaporation, which will lead to an overall decrease of the sea level.	76	17	18	**0.783**	0.198

Note: N = 111, Items displaying an ✓ are correctly formulated statements. Factor loadings > 0.500 are printed in bold. Component 1 explains 41.9% of the variance, component 2 explains 18.6% of the variance.

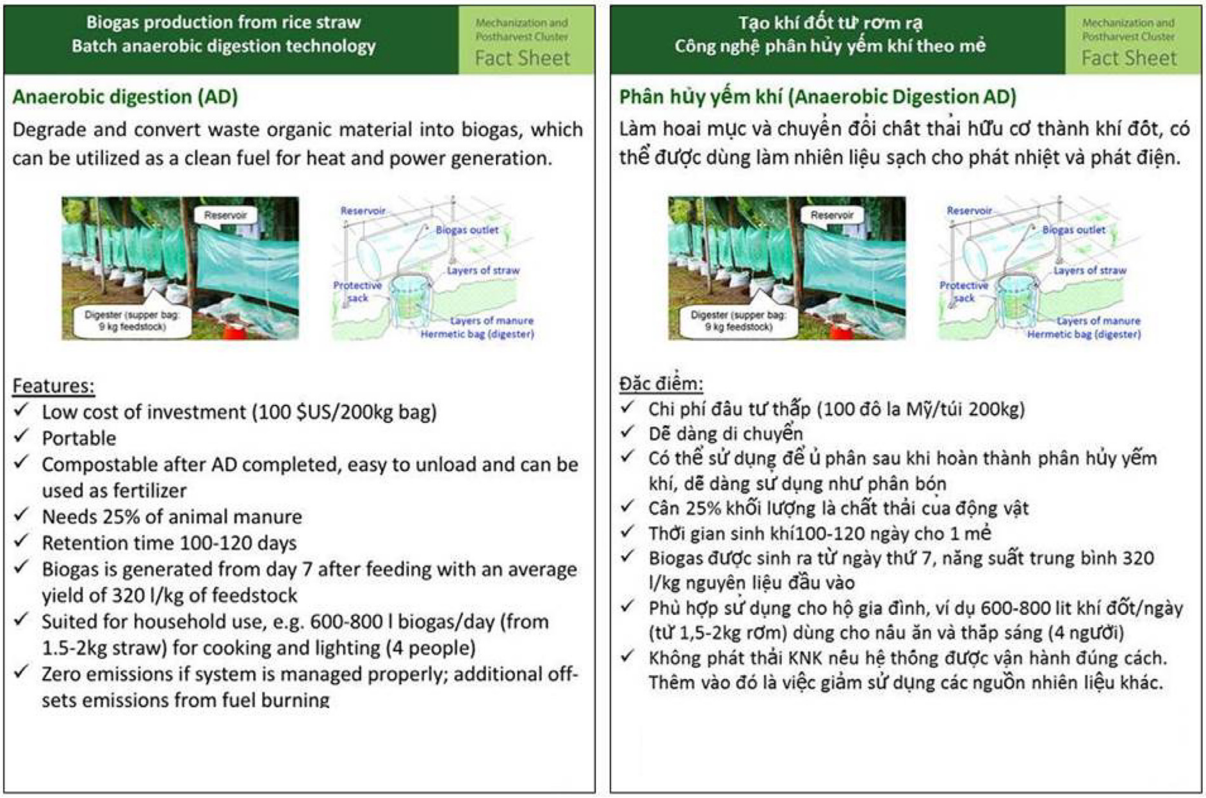

Fig. 1. Fact sheet biogas production from rice straw (English and Vietnamese).

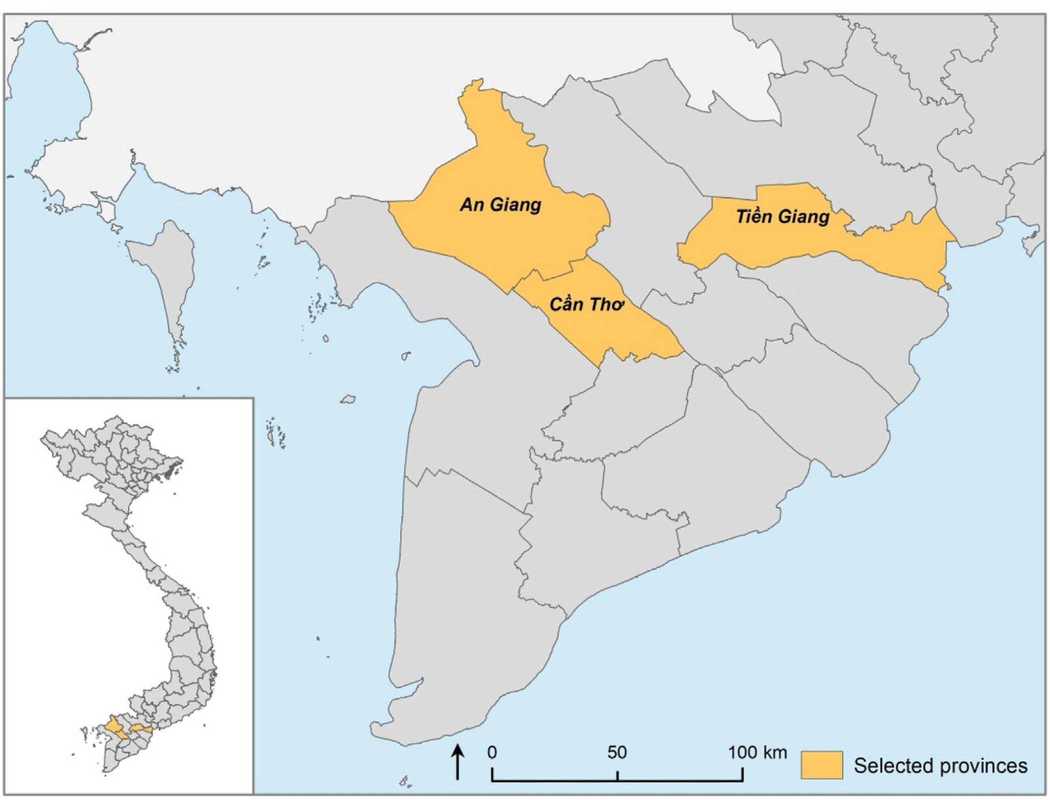

Fig. 2. Map of South Vietnam with provinces where the survey took place highlighted.

3.2. Knowledge

Exploratory factor analysis with principal components as extraction method was applied to investigate the underlying structure of the knowledge items (Table 2). Results show a two-factor solution (KMO = 0.658, χ^2 = 145.05, df = 15, p < 0.001) reflecting the two knowledge dimensions 'knowledge about CO_2 and the greenhouse effect' and 'knowledge concerning expected consequences of climate change' as described by Tobler et all (2012b). Reliability analysis showed a good internal reliability Cronbach's α = 0.699 (N = 6), both sub-scales 'knowledge about CO_2 and the greenhouse effect' (Cronbach's α = 0.583, N = 3) and 'knowledge concerning expected consequences of climate change' (Cronbach's α = 0.703, N = 3) also show good internal reliabilities.

On average participants answered 2.6 (SD = 1.2) knowledge questions correctly (min = 0, max = 5). No farmer answered all six questions correctly.

There was a significant correlation between knowledge and educational status of the farmers r = 0.401, p < 0.001.

3.3. Perceptions of rice straw burning

Five items were used to investigate farmers' perceptions of rice straw burning. Factor analysis with principal components as extraction method revealed two factors (Table 3) (KMO = 0.616, χ^2 = 87.87, df = 10, p < 0.001). Factor one comprises nutrients and pests and accounts for 39.7% of the total variance and factor two comprises of perceptions of consequences accounting for 26.3% of the variance.

3.4. Support from institutions

In general, participants expected rather high levels of support from the different institutions. Participants expected to get most support for rice straw management from their government (M = 4.93, SD = 1.52), from research institutions (M = 4.86, SD = 1.67), other farmers (M = 4.63, SD = 1.66), universities (M = 4.57, 1.77), NGOs (M = 4.36, SD = 2.04) and private companies (M = 3.97, SD = 2.03). A combined latent construct – support from institutions – was created, which shows good reliability Cronbach's α = 0.815 (n = 6).

3.5. Rice straw management practices

3.5.1. Benefit perceptions

Overall, participants perceived high benefits from most of the rice straw management practices apart from rice straw burning (Table 4). The highest benefits were perceived for straw collection practices, cattle feed, and mushroom production. There were significant differences in participants' benefit perceptions for incorporation into the soil when comparing benefits for farmers and benefits for the environment (d = 0.306) but also when comparing benefits for farmers and benefits for the society (d = 0.356). Furthermore, differences in benefit perceptions were also found for straw burning when comparing benefits perceived for the farmer and benefits perceived for the environment (d = 0.418) as well as when comparing benefits perceived for the farmer versus benefits perceived for the society (d = 0.502). Participants perceived significantly higher benefits for the farmers from composting than for the environment (d = 0.193) or for the society (d = 0.209). Participants also perceived significantly higher benefits from the use of straw for cattle feed for the farmer than for the environment (d = 0.267) or the society (d = 0.299). There were significant differences in participants' benefit perceptions for mushroom production. Participants perceived significantly higher benefits for the farmer than the environment (d = 0.253) or the society (d = 0.283) (Table 4). Cohen's d indicates weak to medium-strong differences and, therefore, a mean for the three benefit perceptions was calculated and subsequent analyses will be conducted with the overall mean for each rice straw management practice.

Table 3
Participants' perceptions of rice straw burning, factor loadings, means and standard deviations.

	component			
	1	2	mean	SD
Burning rice straw is good for including nutrients into the soil.	−0.203	**0.795**	4.46	1.91
Burning rice straw is good for killing pests.	0.134	**0.819**	4.64	1.87
Burning rice straw is causing the farmer health problems.	**0.751**	−0.100	4.64	1.87
Burning rice straw is bad for the environment.	**0.859**	−0.104	5.14	1.61
Burning rice straw releases a lot of carbon dioxide.	**0.775**	0.121	4.72	1.93

Note: N = 111. Cronbach's α component 1 = 0.710.

3.5.2. Risk perceptions

Participants perceived the highest risk from rice straw burning followed by incorporation into the soil, biogas production, and mushroom production (Table 4). There were significant differences in risk perceptions for incorporation into the soil. Participants perceived significantly higher risks for the farmers than for the society (d = 0.3080) or the environment (d = 0.123). Participants also perceived higher risks for the farmers concerning mushroom production than for the environment (d = 0.184) or the society (d = 0.190) (Table 4). Since risk perception differences are weak an overall risk perception mean was computed for each rice straw management practice.

3.5.3. Relationship between risk and benefit perceptions

Correlations were calculated for each rice straw management practice. All correlations showed an inverse relationship between perceived risks and benefits. The strongest and highly significant correlations were found for rice straw burning (r = -0.585, p < 0.001), rice straw incorporation into the soil (r = -0.412, p < 0.001), baling (r = -0.383, p < 0.001), and rice straw as cattle feed (r = -0.277, p = 0.003). No correlations between risk and benefit perceptions were found for composting, compacting, mushroom production and biogas production.

3.5.4. Acceptance

Acceptance for the presented rice straw management practices was generally high, apart from rice straw burning, for which participants had very low acceptance (Table 4). There were significant differences in acceptance ratings for straw incorporation into the soil. Participants perceived rice straw incorporation into the soil to be more acceptable for the farmers than for the environment (d = 0.202) or the society (d = 0.163). Furthermore, participants also perceived rice straw burning to be more acceptable for the farmers than for the environment (d = 0.233) or the society (d = 0.301). Since effect sizes are small, an overall acceptance mean was calculated for each straw management practice.

3.6. Factors influencing the acceptance of rice straw management practices

For each rice straw management practice, a multiple regression analysis with the mean acceptance of the particular practice was conducted. Results are presented in Table 5 and show that the particular benefit perceptions are strong predictors for each practice. The higher the perceived benefit the higher is farmers' acceptance of that particular rice straw management practice. Furthermore, farmers' risk perceptions are also a significant predictor for rice straw incorporation into the soil (β = -0.210), rice straw burning (β = -0.203), biogas production (β = -0.180), and cattle feed (β = -0.245). Farmers who associated high risks with these management practices showed lower acceptance for these

Table 4
Benefit perceptions, risk perceptions, and acceptance of rice straw management practices. Comparisons between perceptions for farmers, the environment and the society.

	Incorporation Mean (SD)	Burning Mean (SD)	Composting Mean (SD)	Compacting Mean (SD)	Biogas Mean (SD)	Cattle feed Mean (SD)	Straw collection Mean (SD)	Mushroom Mean (SD)
Benefit								
Farmer	5.01 (1.46)	3.32 (1.88)	5.30 (1.18)	5.11 (1.40)	5.15 (1.50)	5.59 (0.83)	5.68 (0.79)	5.59 (0.91)
Environment	4.52 (1.78)	2.43 (1.66)	4.93 (1.51)	5.03 (1.40)	4.95 (1.56)	5.30 (1.09)	5.55 (0.86)	5.29 (1.19)
Society	4.42 (1.88)	2.58 (1.65)	4.95 (1.45)	5.01 (1.37)	4.99 (1.52)	5.34 (1.03)	5.60 (0.77)	5.33 (1.13)
Farmer vs. Environment	t = 3.21	t = 5.08	t = 3.48	t = 1.26	t = 2.19	t = 3.27	t = 1.42	t = 4.12
	p = 0.002	p < 0.001	p = 0.001	p = 0.209	p = 0.030	p = 0.001	p = 0.158	p < 0.001
Farmer vs. Society	t = 3.93	t = 4.42	t = 3.41	t = 1.42	t = 1.82	t = 2.93	t = 0.92	t = 3.95
	p < 0.001	p < 0.001	p = 0.001	p = 0.160	p = 0.072	p = 0.004	p = 0.361	p < 0.001
Society vs. Environment	t = 0.96	t = -1.97	t = -0.30	t = 0.45	t = -0.75	t = -0.93	t = -1.51	t = -1.39
	p = 0.339	p = 0.052	p = 0.765	p = 0.657	p = 0.452	p = 0.355	p = 0.134	p = 0.167
Risk								
Farmer	2.56 (1.74)	4.38 (1.89)	1.70 (1.35)	1.68 (1.29)	2.03 (1.57)	1.71 (1.32)	1.47 (1.06)	2.04 (1.43)
Environment	2.25 (1.60)	4.31 (1.89)	1.56 (1.13)	1.68 (1.27)	2.05 (1.58)	1.78 (1.34)	1.58 (1.16)	1.78 (1.30)
Society	2.06 (1.50)	4.25 (1.84)	1.56 (1.17)	1.79 (1.39)	1.99 (1.53)	1.77 (1.33)	1.67 (1.25)	1.79 (1.28)
Farmer vs. Environment	t = 2.31	t = 0.54	t = 1.25	t = 0	t = -0.43	t = -0.84	t = -1.20	t = 2.70
	p = 0.023	p = 0.590	p = 0.213	p = 1	p = 0.670	p = 0.402	p = 0.232	p = 0.008
Farmer vs. Society	t = 3.86	t = 0.95	t = 1.27	t = -1.12	t = 0.56,	t = -0.70	t = -2.40	t = 2.58
	p < 0.001	p = 0.343	p = 0.207	p = 0.271	p = 0.574	p = 0.484	p = 0.018	p = 0.011
Society vs. Environment	t = 2.63	t = 1.35	t = 0	t = -1.92,	t = 1.47	t = 0.22	t = -2.28	t = -0.19
	p = 0.010	p = 0.181	p = 1	p = 0.057	p = 0.145	p = 0.828	p = 0.025	p = 0.854
Acceptance								
Farmer	4.52 (1.77)	3.30 (1.93)	5.07 (1.42)	5.05 (1.58)	4.74 (1.69)	5.21 (1.36)	5.32 (1.20)	5.25 (1.32)
Environment	4.15 (1.90)	2.74 (1.79)	5.04 (1.33)	5.12 (1.33)	4.67 (1.61)	5.14 (1.26)	5.23 (1.17)	5.08 (1.41)
Society	4.22 (1.90)	2.86 (1.85)	4.96 (1.42)	5.12 (1.31)	4.61 (1.66)	5.15 (1.30)	5.24 (1.17)	5.14 (1.40)
Farmer vs. Environment	t = 2.86	t = 4.77	t = 0.52	t = -0.87	t = 0.88	t = 0.65	t = 1.23	t = 1.88
	p = 0.005	p < 0.001	p = 0.602	p = 0.385	p = 0.379	p = 0.520	p = 0.220	p = 0.063
Farmer vs. Society	t = 2.49	t = 3.55	t = 1.49	t = -0.88	t = 1.66	t = 0.58,	t = 1.22	t = 1.28
	p = 0.014	p < 0.001	p = 0.140	p = 0.379	p = 0.099	p = 0.566	p = 0.227	p = 0.202
Society vs. Environment	t = -1.15	t = -2.01	t = 2.03	t = 0	t = 1.06	t = -0.23	t = -0.26	t = -1.83
	p = 0.252	p = 0.047	p = 0.045	p = 1	p = 0.291	p = 0.820	p = 0.798	p = 0.071

Note: df = 110, significance level lowered to p < 0.016 (Bonferroni correction for multiple comparisons)

practices. Knowledge about climate change was a significant predictor for the acceptance of rice straw incorporation (β = 0.206), straw composting (β = 0.297), biogas production (β = 0.344), rice straw as cattle feed (β = 0.356), straw collection (β = 0.248), straw compacting (β = 0.341), and rice straw for mushroom production (β = 0.371). Expectations for support had an association with rice straw collection (β = -0.260) and compacting (β = -0.269). Furthermore, being a member of a cooperative is associated with lower levels of acceptance for rice straw burning (β = -0.802). The acceptance of rice straw composting is also influenced by the size of the farm (β = -0.367), with farmers from smaller farms being more accepting of composting. Furthermore, there was a significant association of cultivating only rice (β = 0.908) with the acceptance of biogas production.

3.7. Possibility to use the rice straw management practices in the three cropping seasons

Participants indicated how likely they would be to use the introduced straw management practices in their three cropping seasons. Results show that during the winter–spring season farmers reported use of rice straw for cattle feed, mushroom production or burning (Fig. 3). During the summer–autumn season, participants reported that they would be likely to incorporate their straw but also saw all the other practices, with the exception of burning, as being possible. Burning rice straw was the least possible practice in the summer-autumn season. For the rainy season, farmers reported that they are likely to either have their straw collected or incorporate it into the soil. They are least likely to burn or to use it for mushroom production.

There are significant positive correlations between farmers' acceptance of the rice straw management practices and their possibility to use them in one of the three cropping seasons (Table 6). The strongest correlations were between acceptance of incorporation into the soil and summer–autumn season (r = 0.500) and the rainy season (r = 0.551).

4. Discussion

The present study investigated factors influencing farmers' acceptance of a variety of rice straw management practices in the Mekong Delta, Vietnam. Therefore, farmers' knowledge about climate change was investigated as a possible factor influencing their acceptance of rice straw management practices. The scale to investigate climate change knowledge was originally created to investigate consumers' knowledge of climate change (Tobler et al., 2012b). Factor analysis revealed the same factors for a farmer population and reliability analysis also shows high reliabilities for both sub-scales and for the combined scale of all items. Therefore, it can be concluded that the climate change knowledge scale can also be used to assess knowledge in farmer populations. It becomes clear, however, that farmers have only limited knowledge about climate change especially about the physical knowledge about CO_2 and the greenhouse effect. One possible explanation could be that the items used in that sub-scale are very technical and farmers may not be familiar with the terminology. However, farmers seem to have a good understanding of the consequences of climate change. Farmers' knowledge about the consequences of climate change can possibly be explained by their exposure to extreme weather. It has been shown that Vietnam has seen a change in rainfall and extreme weather over the last decade, which has also been perceived by farmers (Cullen & Anderson, 2017). The items of the scale used to measure knowledge about causes of climate change included items about increasing temperatures and severe weather occurrences. Our results also show that knowledge about climate change is associated with the educational attainment of farmers with those having higher educational attainment levels displaying better knowledge about climate change (r = 0.400).

The results of the present study show that participating farmers

Table 5
Regression analyses for each rice straw management practice separately.

Rice straw incorporation R^2 = 51.7%				Rice straw burning R^2 = 40.5%			
	β	t	p		β	t	p
Benefit incorporation	**0.681**	7.58	**0.000**	Benefit burning	**0.575**	4.83	**0.000**
Risk incorporation	**−0.210**	−2.26	**0.026**	Risk burning	**−0.203**	−2.07	**0.041**
Climate change knowledge	**0.206**	2.14	**0.035**	Climate change knowledge	−0.089	−0.79	0.433
Support expectations	−0.051	−0.52	0.605	Support expectations	0.026	−0.24	0.814
Age	−0.011	−1.10	0.274	Age	−0.003	−0.27	0.792
Membership cooperative	−0.011	−0.05	0.964	Membership cooperative	**−0.820**	−2.96	**0.004**
Farm size	**−0.301**	−2.31	**0.023**	Farm size	0.039	0.26	0.792
Single crop rice	0.174	0.59	0.557	Single crop rice	0.185	0.56	0.578
				Perception of burning	−0.105	−1.10	0.273
Rice straw composting R^2 = 29.3%				Biogas production R^2 = 38.3%			
	β	t	p		β	t	p
Benefit composting	0.338	3.71	0.000	Benefit biogas	0.493	5.61	0.000
Risk composting	−0.137	−1.30	0.196	Risk biogas	**−0.180**	−2.96	**0.024**
Climate change knowledge	**0.297**	3.30	**0.001**	Climate change knowledge	**0.344**	3.47	**0.001**
Support expectations	−0.159	−1.74	0.084	Support expectations	−0.055	−0.54	0.591
Age	−0.004	−0.38	0.708	Age	0.002	0.16	0.876
Membership cooperative	0.088	0.38	0.703	Membership cooperative	−0.421	−1.68	0.097
Farm size	**−0.367**	−2.94	**0.004**	Farm size	−0.226	−1.69	0.095
Single crop rice	0.176	0.64	0.523	Single crop rice	**0.908**	3.01	**0.003**
Rice straw as cattle feed R^2 = 43.0%				Rice straw collection R^2 = 24.3%			
	B	t	p		β	t	p
Benefit cattle feed	**0.489**	4.39	**0.000**	Benefit collection	**0.476**	3.02	**0.003**
Risk cattle feed	**−0.245**	−3.11	**0.002**	Risk collection	−0.070	−0.72	0.476
Climate change knowledge	**0.356**	4.68	**0.000**	Climate change knowledge	**0.248**	3.09	**0.003**
Support expectations	−0.070	−0.92	0.361	Support expectations	**−0.260**	−3.19	**0.002**
Age	−0.005	−0.67	0.502	Age	−0.003	−0.38	0.702
Membership cooperative	−0.292	−1.56	0.123	Membership cooperative	−0.022	−0.11	0.915
Farm size	−0.030	−0.29	0.770	Farm size	0.020	0.19	0.854
Single crop rice	0.160	0.72	0.474	Single crop rice	0.433	1.77	0.080
Rice straw compacting R^2 = 29.2%				Mushroom production R^2 = 48.4%			
	B	t	p		β	t	p
Benefit compacting	0.347	4.15	0.000	Benefit mushroom	0.676	7.13	0.000
Risk compacting	−0.161	−1.74	0.085	Risk mushroom	−0.024	−0.31	0.754
Climate change knowledge	**0.371**	4.13	**0.000**	Climate change knowledge	**0.341**	4.27	**0.000**
Support expectations	**−0.269**	−2.96	**0.004**	Support expectations	−0.092	−1.20	0.233
Age	−0.015	−1.62	0.109	Age	−0.010	−1.30	0.196
Membership cooperative	−0.119	−0.53	0.600	Membership cooperative	0.030	0.15	0.880
Farm size	−0.084	−0.69	0.490	Farm size	−0.094	−0.92	0.363
Single crop rice	0.266	0.98	0.331	Single crop rice	0.264	1.13	0.260

Note: N for each regression analysis = 111. Significant results are in bold face.

perceived a variety of risks from rice straw burning, such as health risks, pollution and an increase of CO_2. In fact, it has been shown that burning straw in small stacks with a relatively high moisture content emitted high Carbon monoxide, methane, and non-methane volatile organic carbon (Arai et al., 2015). Burning biomass also produces hydrocarbon and reactive nitrogen emissions, which react to form tropospheric ozone (Smith et al., 2008). The smoke contains a range of aerosols which can have either a warming or cooling effect on the atmosphere (Smith et al., 2008). In general, farmers indicated that they perceive low benefits and high risks from rice straw burning. However, farmers' perceptions of benefits differed and farmers perceived greater benefits for themselves than for the society or the environment. Rice straw burning was the least accepted straw management practice but both benefit and risk perceptions were significant predictors for its acceptance. The strongest predictor, however, was farmers' membership of a farming association indicating that farmers who do not belong to a farming association show higher levels acceptance for rice straw burning; in other words, a farmer who is a member of a farming association showed lower acceptance for rice straw burning. A recent study in the Mekong Delta also revealed that membership of agricultural cooperatives has a positive effect on eco-friendly rice cultivation practices (Tu et al., 2018). Nonetheless, almost all farmers indicated that they have burnt rice straw in the past. Furthermore, participants also indicated that they are very likely to burn their rice straw in the next winter-spring cropping season. There are different explanations for these results. On the one hand, the benefits of burning straw for the farmer, for example, are fast removal of straw in fields which are difficult to access, or fast removal of straw between cropping seasons. These benefits may outweigh the associated risks. Furthermore, it might be cognitive dissonance, even though farmers perceive high risks of burning rice straw they will find explanations to justify taking those risks. For example, if fields are difficult to access farmers may think they have no other option than burning. Furthermore, farmers might feel that the small contribution they can make as an individual does not have a significant effect if others do not contribute in the same way. These results are important for policymakers. On the one hand, although farmers know about the risks associated with burning, simple prohibition without enforcement does not seem to work, which

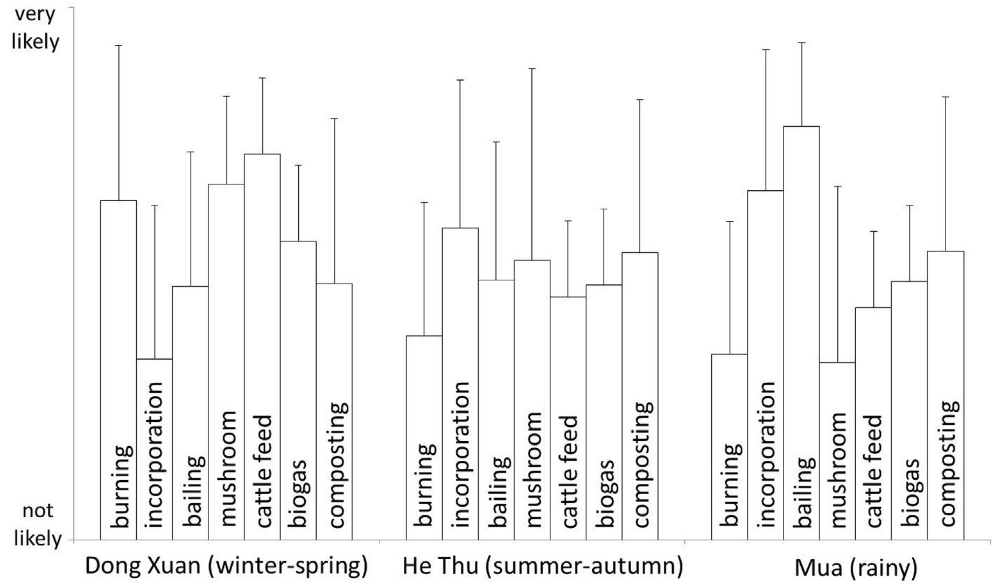

Fig. 3. Comparison of possibility to use the rice straw management options in the three cropping seasons.

Table 6
Pearson correlations acceptance of rice straw management methods and likeliness to use one of the practices in the three different seasons.

	Dong Xuan Winter – Spring	He Thu Summer – Autumn	Mua Rainy
Incorporation into the soil	0.249**	0.500**	0.551**
Rice straw burning	0.447**	0.391**	0.235**
Rice straw composting	0.361**	0.251**	0.304**
Biogas production	0.289**	0.334**	0.294**
Cattle feed	0.334**	0.221**	0.091
Straw collection	0.312**	0.175	0.133

Note: $p < 0.01$ **.

indicates that straw management options are lacking for farmers especially in the winter-spring season.

For all other rice straw management practices, perceived benefits were a strong predictor for acceptance. It has to be noted that for most practices, participants perceived greater benefits for the farmers than for the environment or the society. Results of the present study also show that risk perceptions only played a minor role but were a significant predictor for the acceptance of rice straw incorporation into the soil, straw burning, biogas production, and cattle feed. It has been shown that benefit perceptions can outweigh risk perceptions which could be a possible explanation for the dominating effect of benefit perceptions (Fischhoff, Slovic, & Lichtenstein, 1979). Farmers in the present study reported perceiving high benefits and low risks from the rice straw management practices (except rice straw burning as discussed before). The rice straw management options, incorporation into the soil, baling, and cattle feed showed medium-strong inverse correlations between benefit and risk perceptions confirming that for some practices risks and benefits are negatively correlated in people's minds, even though they may be positively correlated in the environment (Alhakami & Slovic, 1994; Ekane, Slovic, Kjellen, & Westlund, 2016; Finucane et al., 2000). It has been argued that the reason for this inverse correlation is an affective feeling when risks and benefits are judged (Alhakami & Slovic, 1994; Finucane et al., 2000). For example, if farmers favor, or judge the practice as desirable they may judge their risks as low and benefits as high and vice versa if they judge the practice as undesirable (e.g. straw burning). This so-called affect heuristic is based on the experiential system (Slovic, Finucane, Peters, & Macgregor, 2004), which is often described as fast, holistic and relying on emotional images and narratives. The rice straw management practices which showed an inverse correlation to risks and benefits were all well known to the farmers and had been practiced in the past (Fig. 4). Therefore, farmers may have images in mind when judging familiar rice straw management practices whereas for less known and used practices e.g. biogas production farmers do not only rely on the experiential system but also on the analytical system (Slovic et al., 2004). The analytical system is based on logical reasoning, is slow, needs resources and requires conscious control. In the present study, benefit and risk perceptions as well as knowledge about climate change were determinates of the acceptance of biogas production. Relying on knowledge and the absence of the inverse correlation between perceived risks and benefits are good indicators that farmers of the present study used the analytical system to evaluate the biogas production. Few farmers indicated first-hand experience of biogas production and, therefore, personal associations with that practice might be scarce. Furthermore, knowledge about climate change was also a predictor for the acceptance of straw incorporation into the soil, composting, cattle feed, baling, compacting, and mushroom production. It has been shown that, for example, knowledge about global warming and climate change increases concern about the risks of climate change and this in turn increased responsibility to help to solve the problem (Milfont, 2012).

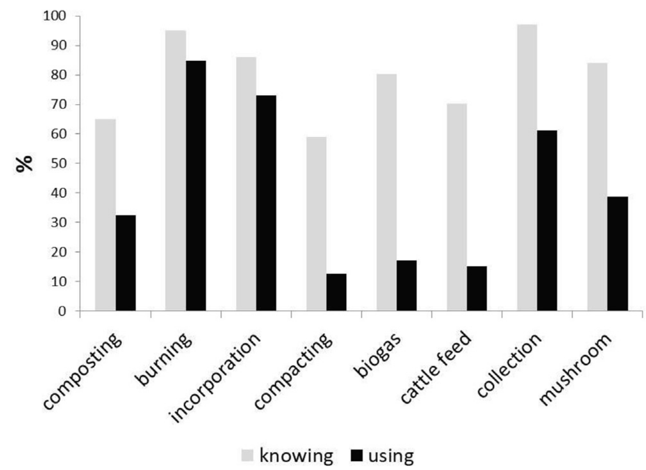

Fig. 4. Percentage of farmers knowing the straw management practice and having applied the practice in the past.

Little however is known in farming populations about the interplay between knowledge about climate change and action to solve this problem.

We also asked farmers about their perceptions of support from institutions. The original version of the questionnaire asked about trust in institutions, since it was shown that trust is a component for the acceptance of new technologies (Siegrist et al., 2000). However, it was not possible to ask a trust question to Vietnamese farmers and, therefore, the question was rephrased to ask about support from institutions. The results show that support from institutions is a significant predictor for baling and compacting rice straw. Farmers need support from different actors; especially from the government and research institutions to have access to straw collection machinery since participants are all smallholder farmers with < 2 ha of cropping land and limited access to machinery. Consequently, if management practices are introduced which need special machinery not available to the farmers it needs to be ensured that farmers have access to these machines. Furthermore, it needs to be affordable for farmers to rent these machines. Finances are limited to smallholder farmers and, therefore, farmers need to have different options to meet their needs. For straw management options such as straw incorporation into the soil and composting farm size was a significant predictor for the acceptance. In both cases, farmers with a smaller field were more likely to accept these two practices which indicate that it might be easier to use these two practices on smaller plots rather than big fields.

It is important to note some limitations of the present study. The study was conducted with a small cohort of rice farmers from three provinces in the Mekong Delta, Vietnam. Consequently, results obtained may only represent the cases of the farmers participating. All participating farmers came from a list of farmers participating in other development projects; this may lead to increased social desirability. Farmer characteristics such as gender, education, mean age and household composition are comparable with those of other studies in the Mekong Delta (Berg, Ekman Söderholm, Söderström, & Tam, 2017; Berg & Tam, 2018; Sattaka, Pattaratuma, & Attawipakpaisan, 2017). However, results should be interpreted with caution as they may not represent the whole rice farming community across the provinces or even the Mekong Delta. All data of the present study rely on self-reported measures and are, therefore, susceptible to biases especially social desirability. Finally, it was not possible to gender disaggregate the data since only ten farmers were female. Studies, however, have shown that women, in general, show greater concern for the environment than men (Davidson & Freudenberg, 1996) and that they perceive more risks than men (Gustafson, 1998). Moreover, in Vietnam, covertly held family values are often embraced ahead of the ones promulgated by the state (Burr, 2014). Therefore, when communicating rice straw management practices it might be of an advantage to also communicate to non-farming female spouses.

5. Conclusions and implications

The findings of the present study are important for researchers and policymakers. The present study has shown that farmers in Vietnam lack knowledge about the physical aspects of climate change. This knowledge is essential to create tailored interventions for farmers for sustainable agricultural practices, such as rice straw management. Furthermore, when trying to implement policies regarding rice straw management it is important to consider factors such as farm size, risk and benefit perceptions. The present study revealed that farmers used the experiential system to evaluate known rice straw management practices but used the analytical system to evaluate less known practices. Therefore, the acceptance of new management practices will depend upon farmers' perceptions of risks in addition to benefit perceptions. This needs consideration when designing intervention material, which should also contain risk communication and risk mitigation strategies.

With special regard to rice straw burning it has to be noted that farmers are aware of the risks, they, in fact, perceive very high risks and low benefits from rice straw burning. However, farmers still indicated that they will use this straw management method at least for one cropping season. It will be necessary to investigate the constraints such as the financial capacity to rent appropriate machinery to collect the straw or time constraints to compost and incorporate the straw.

The present study has shown how farmers evaluate rice straw management practices and which factors play a role in decision-making processes. For successful implementation of new practices it will be important to address these factors (risk and benefit perceptions, knowledge about climate change) or account for limiting factors such as farm size or multiple crops per year.

Funding

The research was supported by the Swiss Agency for Development and Cooperation (SDC) project CORIGAP – Closing Rice Yield Gaps (grant number 81016734) and by the Federal Ministry of Economic Cooperation and Development (Germany) Scalable straw management options for improved farmer's livelihoods, sustainability, and low environmental footprint in rice-based ecosystems. GIZ Grant Agreement 15.7860.8-001.00). The position of B. O. Sander at IRRI was funded by the Climate and Clean Air Coalition (CCAC) (DTIE14-EN040) and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which is carried out with support from CGIAR Fund Donors and through bilateral funding agreements. For details please visit https://ccafs.cgiar.org/donors. The views expressed in this document cannot be taken to reflect the official opinion of these organizations.

CRediT authorship contribution statement

Melanie Connor: Conceptualization, Methodology, Formal analysis, Visualization, Writing - original draft, Writing - review & editing. **Annalyn H. de Guia:** Software, Validation, Data curation. **Reianne Quilloy:** Methodology, fact sheets. **Hung Van Nguyen:** Conceptualization, Methodology. **Martin Gummert:** Conceptualization, Funding acquisition. **Bjoern Ole Sander:** Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank Dr. My Phung for organizing translators and helping to coordinate the data collection. We also would like to thank all participating farmers.

References

Abid, M., Schilling, J., Scheffran, J., & Zulfiqar, F. (2016). Climate change vulnerability, adaptation and risk perceptions at farm level in Punjab, Pakistan. *Science of The Total Environment, 547*, 447–460. https://doi.org/10.1016/j.scitotenv.2015.11.125.

Agarwal, S., LeFevre, A. E., Lee, J., L'Engle, K., Mehl, G., Sinha, C., & Labrique, A. (2016). Guidelines for reporting of health interventions using mobile phones: mobile health (mHealth) evidence reporting and assessment (mERA) checklist. *BMJ, 352*.

Alhakami, A. S., & Slovic, P. (1994). A psychological study of the inverse relationship between perceived risk and perceived benefit. *Risk Analysis, 14*, 1085–1096.

Apata, T. G. (2011). Factors influencing the perception and choice of adaptation measures to climate change among farmers in Nigeria. *Journal of Agriculture and Environment for International Development, 2*(4), 74–83.

Arai, H., Hosen, Y., Pham Hong, V. N., Thi, N. T., Huu, C. N., & Inubushi, K. (2015). Greenhouse gas emissions from rice straw burning and straw-mushroom cultivation in a triple rice cropping system in the Mekong Delta. *Soil Science and Plant Nutrition, 61*(4), 719–735. https://doi.org/10.1080/00380768.2015.1041862.

Bain, P. G., Hornsey, M. J., Bongiorno, R., & Jeffries, C. (2012). Promoting pro-environmental action in climate change deniers. *Nature Climate Change, 2*(8), 603. https://doi.org/10.1038/nclimate1636.

Belay, A., Recha, J. W., Woldeamanuel, T., & Morton, J. F. (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture & Food Security, 6*(1), 24. https://doi.org/10.1186/s40066-017-0100-1.

Berg, H., Ekman Söderholm, A., Söderström, A.-S., & Tam, N. T. (2017). Recognizing wetland ecosystem services for sustainable rice farming in the Mekong Delta, Vietnam. *Sustainability Science, 12*(1), 137–154. https://doi.org/10.1007/s11625-016-0409-x.

Berg, H., & Tam, N. T. (2018). Decreased use of pesticides for increased yields of rice and fish-options for sustainable food production in the Mekong Delta. *Science of The Total Environment, 619–620*, 319–327. https://doi.org/10.1016/j.scitotenv.2017.11.062.

Bord, R. J., O'Connor, R. E., & Fisher, A. (2000). In what sense does the public need to understand global climate change? *Public Understanding of Science, 9*(3), 205–218. https://doi.org/10.1088/0963-6625/9/3/301.

Broomell, S. B., Budescu, D. V., & Por, H.-H. (2015). Personal experience with climate change predicts intentions to act. *Global Environmental Change, 32*, 67–73. https://doi.org/10.1016/j.gloenvcha.2015.03.001.

Burr, R. (2014). The complexity of morality: Being a "good child" in Vietnam? *Journal of Moral Education, 43*(2), 156–168. https://doi.org/10.1080/03057240.2014.893421.

Cicerone, R. J., & Oremland, R. S. (1988). Biogeochemical aspects of atmospheric methane. *Global Biogeochemical Cycles, 2*(4), 299–327. https://doi.org/10.1029/GB002i004p00299.

Comoe, H., & Siegrist, M. (2015). Relevant drivers of farmers' decision behavior regarding their adaptation to climate change: A case study of two regions in Cote d'Ivoire. *Mitigation and Adaptation Strategies for Global Change, 20*(2), 179. https://doi.org/10.1007/s11027-013-9486-7.

Cullen, A. C., & Anderson, C. L. (2017). Perception of Climate Risk among Rural Farmers in Vietnam: Consistency within Households and with the Empirical Record. *Risk Analysis, 37*(3).

Cullen, A. C., Anderson, C. L., Biscaye, P., & Reynolds, T. W. (2018). Variability in cross-domain risk perception among smallholder farmers in mali by gender and other demographic and attitudinal characteristics. *Risk Analysis: An Official Publication of the Society for Risk Analysis, 38*(7), 1361–1377. https://doi.org/10.1111/risa.12976.

Dang, H. L., Li, E., Nuberg, I., & Bruwer, J. (2014a). Farmers' assessments of private adaptive measures to climate change and influential factors: A study in the Mekong Delta, Vietnam. *Natural Hazards, 71*(1), 385–401. https://doi.org/10.1007/s11069-013-0931-4.

Dang, H. L., Li, E., Nuberg, I., & Bruwer, J. (2014b). Understanding farmers' adaptation intention to climate change: A structural equation modelling study in the Mekong Delta, Vietnam. *Environmental Science and Policy, 41*, 11–22. https://doi.org/10.1016/j.envsci.2014.04.002.

Davidson, D. J., & Freudenberg, W. R. (1996). Gender and environmental risk concerns. *Environment and Behaviour, 28*(3), 302–339.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340. https://doi.org/10.2307/249008.

Dobermann, A., & Fairhurst, T. H. (2002). Rice Straw Management. *Better Crops International, 16*.

Ekane, N., Slovic, P., Kjellen, M., & Westlund, H. (2016). Risk and benefit judgment of excreta as fertilizer in agriculture: An exploratory investigation in Rwanda and Uganda. *Human & ecological risk assessment, 22*(3), 639–666. https://doi.org/10.1080/10807039.2015.1100515.

Finucane, M. L., Alhakami, A., Slovic, P., & Johnson, S. M. (2000). The affect heuristic in judgments of risks and benefits. *Journal of Behavioral Decision Making, 13*(1), 1–17. https://doi.org/10.1002/(SICI)1099-0771(200001/03)13:1 < 1::AID-BDM333 > 3.0.CO2-S.

Fischhoff, B., Slovic, P., & Lichtenstein, S. (1979). Weighing the risks: Which risks are acceptable? *Environment, 2*(4), 17–38.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., & Combs, B. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Policy Sciences, 9*(2), 127–152. https://doi.org/10.1007/BF00143739.

Gadde, B., Bonnet, S., Menke, C., & Garivait, S. (2009). Air pollutant emissions from rice straw open field burning in India, Thailand and the Philippines. *Environmental Pollution, 157*(5), 1554–1558. https://doi.org/10.1016/j.envpol.2009.01.004.

GRiSP (2013). *Rice Almanac* (4th ed.). Los Baños (Philippines): International Rice Research Institute.

Gustafson, P. E. (1998). Gender differences in risk perception: Theoretical and methodological perspectives. *Risk Analysis, 18*, 805–811.

Habtemariam, L. T., Gandorfer, M., Kassa, G. A., & Heissenhuber, A. (2016). Factors influencing smallholder farmers' climate change perceptions: a study from farmers in Ethiopia. *Environmental Management, 58*(2), 343–358. https://doi.org/10.1007/s00267-016-0708-0.

Holter, J. B., & Young, A. J. (1992). Methane Prediction in Dry and Lactating Holstein Cows1. *Journal of Dairy Science, 75*(8), 2165–2175. https://doi.org/10.3168/jds.S0022-0302(92)77976-4.

Hong Van, N. P., Nga, T. T., Arai, H., Hosen, Y., Chiem, N. H., & Inubushi, K. (2014). Rice straw management by farmers in a triple rice production system in the mekong delta, Viet Nam. *Tropical Agriculture and Development, 58*(4), 155–162. https://doi.org/10.11248/jsta.58.155.

Janis, L. D., Poppy, M., Robert, B., & Shorna, A. (2016). Which moral foundations predict willingness to make lifestyle changes to avert climate change in the USA? *PLoS ONE, 11*(10), e0163852. https://doi.org/10.1371/journal.pone.0163852.

Kontgis, C., Schneider, A., & Ozdogan, M. (2015). Mapping rice paddy extent and intensification in the Vietnamese Mekong River Delta with dense time stacks of Landsat data. *Remote Sensing of Environment, 169*, 255–269. https://doi.org/10.1016/j.rse.2015.08.004.

Lasco, R. D., Espaldon, M. L. O., & Habito, C. M. D. (2016). Smallholder farmers' perceptions of climate change and the roles of trees and agroforestry in climate risk adaptation: Evidence from Bohol, Philippines. *Agroforestry Systems, 90*(3), 521–540. https://doi.org/10.1007/s10457-015-9874-y.

Mandal, K. G., Misra, A. K., Hati, K. M., Bandyopadhyay, K. K., Ghosh, P. K., & Mohanty, M. (2004). Rice residue- management options and effects on soil properties and crop productivity. *Journal of Food, Agriculture and Environment, 2*(1), 224–231.

Maraseni, T. N., Deo, R. C., Qu, J., Gentle, P., & Neupane, P. R. (2018). An international comparison of rice consumption behaviours and greenhouse gas emissions from rice production. *Journal of Cleaner Production, 172*, 2288–2300. https://doi.org/10.1016/j.jclepro.2017.11.182.

Marris, C., Langford, I., Saunderson, T., & Oriordan, T. (1997). Exploring the "psychometric paradigm": Comparisons between aggregate and individual analyses. *Risk Analysis, 17*(3), 303–312.

Milfont, T. L. (2012). The interplay between knowledge, perceived efficacy, and concern about global warming and climate change: A one-year longitudinal study. *Risk Anal, 32*(6), 1003–1020. https://doi.org/10.1111/j.1539-6924.2012.01800.x.

Mwangi, M., Kariuki, S. M., & Egerton, K. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development, 6*(5).

Nguyen, H. V., Maguyon-Detras, M. C., Migo, M. V., Quilloy, R., Balingbing, C., Chivenge, P., & Gummert, M. (2020). Rice straw overview: Availability, properties, and management practices. In M. Gummert, N. V. Hung, P. Chivenge, & B. Douthwaite (Eds.). *Sustainable Rice Straw Management* (pp. 1–13). Cham: Springer International Publishing.

Nguyen, H. V., Nguyen, C. D., Tran, T. V., Hau, H. D., Nguyen, N. T., & Gummert, M. (2016). Energy efficiency, greenhouse gas emissions, and cost of rice straw collection in the mekong river delta of vietnam. *Field Crops Research, 198*, 16–22. https://doi.org/10.1016/j.fcr.2016.08.024.

Ponnamperuma, F. N. (1984). Straw as a source of nutrients for wetland rice. *Organic Matter and Rice* (pp. 117–136). IRRI: Los Banos, Philippines.

Romasanta, R. R., Sander, B. O., Gaihre, Y. K., Alberto, M. C., Gummert, M., Quilty, J., ... Wassmann, R. (2017). How does burning of rice straw affect CH4 and N2O emissions? A comparative experiment of different on-field straw management practices. *Agriculture, Ecosystems & Environment, 239*, 143–153. https://doi.org/10.1016/j.agee.2016.12.042.

Saothongnoi, V., Amkha, S., Inubushi, K., & Smakgahn, K. (2014). Effect of rice straw incorporation on soil properties and rice yield. *Thai Journal of Agricultural Science, 47*(1), 7–12.

Sattaka, P., Pattaratuma, S., & Attawipakpaisan, G. (2017). Agricultural extension services to foster production sustainability for food and cultural security of glutinous rice farmers in Vietnam. *Kasetsart Journal of Social Sciences, 38*(1), 74–80. https://doi.org/10.1016/j.kjss.2016.05.003.

Shibata, M. N. I. o. A. I., Kukizaki, Ibaraki (Japan)), Terada, F., Iwasaki, K., Kurihara, M., & Nishida, T. (1992). Methane production in heifers, sheep and goats consuming diets of various hay-concentrate ratios. v. 63.

Siegrist, M., Cvetkovich, G., & Roth, C. (2000). Salient value similarity, social trust, and risk/benefit perception. *Risk Analysis, 20*(3), 353–362. https://doi.org/10.1111/0272-4332.203034.

Slovic, P. (1987). Perception of risk. *Science, 236*, 280–287.

Slovic, P., Finucane, M. L., Peters, E., & Macgregor, D. G. (2004). Risk as Analysis and Risk as Feelings: Some Thoughts about Affect, Reason, Risk, and Rationality. *Risk Analysis, 24*(2), 311–322. https://doi.org/10.1111/j.0272-4332.2004.00433.x.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., ... Smith, J. (2008). Greenhouse gas mitigation in agriculture. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 363*(1492), 789–813. https://doi.org/10.1098/rstb.2007.2184.

Spence, A., Poortinga, W., Butler, C., & Pidgeon, N. F. (2011). Perceptions of climate change and willingness to save energy related to flood experience. *Nature Climate Change, 1*, 46–49.

Spence, A., Poortinga, W., & Pidgeon, N. (2012). The psychological distance of climate change. *Risk Analysis, 32*(6), 957–972. https://doi.org/10.1111/j.1539-6924.2011.01695.x.

Streets, D. G., Yarber, K. F., Woo, J. H., & Carmichael, G. R. (2003). Biomass burning in Asia: Annual and seasonal estimates and atmospheric emissions. *Global Biogeochem Cycles, 17*.

Stuart, A. M., Devkota, K. P., Sato, T., Pame, A. R. P., Balingbing, C., My Phung, N. T., ... Singleton, G. R. (2018). On-farm assessment of different rice crop management practices in the Mekong Delta, Vietnam, using sustainability performance indicators. *Field Crops Research, 229*, 103–114. https://doi.org/10.1016/j.fcr.2018.10.001.

Tey, Y., Li, E., Bruwer, J., Abdullah, A., Brindal, M., Radam, A., ... Darham, S. (2014). The relative importance of factors influencing the adoption of sustainable agricultural practices: A factor approach for Malaysian vegetable farmers. *Sustainability Science, 9*(1), 17–29. https://doi.org/10.1007/s11625-013-0219-3.

Tobler, C., Visschers, V. H. M., & Siegrist, M. (2012a). Addressing climate change: Determinants of consumers' willingness to act and to support policy measures. *Journal of Environmental Psychology, 32*(3), 197–207. https://doi.org/10.1016/j.jenvp.2012.02.001.

Tobler, C., Visschers, V. H. M., & Siegrist, M. (2012b). Consumers' knowledge about climate change. *Climatic Change, 114*(2), 189–209. https://doi.org/10.1007/s10584-011-0393-1.

Tu, V. H., Can, N. D., Takahashi, Y., Kopp, S. W., & Yabe, M. (2018). Modelling the factors affecting the adoption of eco-friendly rice production in the Vietnamese Mekong Delta. *Cogent Food & Agriculture, 4*(1), 1432538. https://doi.org/10.1080/23311932.2018.1432538.

Vu, T. K. V., Vu, D. Q., Jensen, L. S., Sommer, S. G., & Bruun, S. (2015). Life cycle assessment of biogas production in small-scale household digesters in Vietnam. *Asian-Australas J Anim Sci, 28*(5), 716–729. https://doi.org/10.5713/ajas.14.0683.

Wassmann, R., Lantin, R. S., Neue, H. U., Buendia, L. V., Corton, T. M., & Lu, Y. (2000). Characterization of methane emissions from rice fields in Asia. III. Mitigation options and future research needs. *Nutrient Cycling in Agroecosystems, 58*(1), 23–36. https://doi.org/10.1023/A: 1009874014903.

Yagi, K., & Minami, K. (1990). Effect of organic matter application on methane emission from some Japanese paddy fields. *Soil Science and Plant Nutrition, 36*(4), 599–610. https://doi.org/10.1080/00380768.1990.10416797.

Yoshida, S. (1981). Fundamentals of Rice Crop Science. Los Banos, Philippines: IRRI.