Aquaculture International (2020) 28:2093–2109
https://doi.org/10.1007/s10499-020-00577-2

Uneven adoption of tilapia aquaculture in rural Solomon Islands

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Received: 22 October 2019 / Accepted: 8 July 2020 / Published online: 27 July 2020

Abstract
Across many Pacific Island Countries, food insecurity and malnutrition are on the rise. In response, governments, development agencies, and non-governmental organisations are promoting small-scale aquaculture as a complement to fish supplied through coastal fisheries. While small-scale aquaculture has been widely adopted in parts of Asia and Africa, its adoption in rural Pacific Island communities remains relatively low. In this paper, we draw on Diffusion of Innovation theory and apply a classification tree analysis to model the influence of farmers' socio-economic attributes, communication channels, and attributes of the innovation, on the adoption of tilapia aquaculture. We compare 40 tilapia aquaculture adopters with 40 non-adopters in rural Solomon Islands. Our results show that farmers' socio-economic attributes have the highest influence on tilapia aquaculture adoption. Tilapia aquaculture adopters were older, male, less subsistence-oriented, and had lower material styles of life than non-adopters. Information regarding tilapia aquaculture was most shared through informal channels, including relatives and word-of-mouth, compared with formal sources (e.g. fisheries extension officers, expert farmers, pamphlets, and posters). Lastly, while tilapia aquaculture was seen as compatible with socio-cultural norms and livelihood demands, its relative advantage and observability in comparison with other livelihood activities were perceived as low. Overall, this study suggests that tilapia aquaculture (and associated benefits) is not reaching the poorest and vulnerable groups (e.g. women or subsistence-oriented households) in rural Solomon Islands. These findings point to a need for in-depth understanding of socio-economic attributes of farmers, thus ensures strategies to support marginalised groups to participate in and benefit from tilapia aquaculture. The study also highlights the need to better utilise informal and locally appropriate communication channels to effectively support the spread of tilapia aquaculture in rural Pacific Islands contexts. Ultimately, this research can inform small-scale aquaculture development policies of the Government of Solomon Islands, and other Pacific Island Countries, to support the sector in contributing to rural food and nutritional security.

Keywords Tilapia · Aquaculture · Adoption · Solomon Islands · Diffusion of innovation

Introduction

Food and nutritional insecurity among Pacific Islanders are expected to worsen in the near future (Hughes and Lawrence 2005). Processed foods, high in carbohydrates and fats, are increasingly imported and are eroding once healthy traditional diets (Secretariat of the Pacific Community and CSIRO 2011; Sievert et al. 2019; Snowdon et al. 2013). Limited income and rapid population growth are also contributing factors, as they reduce access to nutrient-rich food (Connell 2015). As a result, malnutrition among vulnerable groups, such as women and children, remain unacceptably high across Pacific Island Countries (Secretariat of the Pacific Community and CSIRO 2011). For instance, recent estimates from Fiji, Nauru, Solomon Islands, Tonga, Tuvalu, and Vanuatu suggest that 18% of children under 5 years old are stunted and 38% of pregnant women are anaemic (United Nations Children's Fund 2017). These numbers are higher in Solomon Islands, where childhood stunting affects an estimated 33% of children under 5 (ibid). Such increased incidence of food insecurity and malnutrition presents significant challenges for meeting global nutrition targets (e.g. SDG 2.2 aims to end all forms of malnutrition by 2030) and exerts pressure on the Pacific Island Countries already under-resourced health services, thus further limiting individual and national development.

Fish provides an important source of protein and micronutrients and can contribute to food and nutritional security (Bogard et al. 2016; Hicks et al. 2019). Yet, fish in Pacific Island Countries is largely supplied by coastal fisheries, which are experiencing a decline in supply due to unsustainable fishing efforts coupled with the effects of climate change (Anon 2013; Bell et al. 2009; Valmonte-Santos et al. 2016). Fish from small-scale aquaculture can, therefore, provide an alternative source of animal protein and essential micro-nutrients (Amos et al. 2014; Nandlal 2012). Indeed, small-scale tilapia aquaculture has been proposed as a strategy to help address the food and nutritional insecurity challenge in the Pacific (Amos et al. 2014; Pickering 2010).

Despite the potential contribution of tilapia aquaculture to food and nutritional security (Pickering 2010), its adoption by rural households in the Pacific Islands remains low (Blythe et al. 2017). In Solomon Islands, the Government's National Tilapia Action Plan (2010–2015) describes the challenges facing the sector (Ministry of Fisheries and Marine Resources 2010). These challenges include a lack of knowledge and skills to grow tilapia, tilapia's slow growth and low fecundity, difficulty sourcing feed, and the limited local demand for tilapia compared with marine fish (Harohau et al. *in press*). Yet the barriers highlighted in the action plan focus primarily on biological and technological aspects, with limited attention to the social dimensions of small-scale aquaculture. Amos et al. (2014) suggest that such limited engagement with the social dimensions of aquaculture extends across the context of aquaculture development in the Pacific. People's perceptions, choices, and assets are central to the adoption of aquaculture and influence the potential of aquaculture to deliver sustainable development outcomes (Slater et al. 2013). As such, understanding the social dimensions that shape the adoption of aquaculture is as important as understanding the biological and technological dimensions to ensure its potential positive impacts are realised (Krause et al. 2015; Slater et al. 2013).

Towards this aim, we draw on the Diffusion of Innovation theory to explore the influence of social dimensions on the adoption of tilapia aquaculture (Rogers 2003). Through an empirical study with 80 rural farmers, we examine the influence of socio-economic attributes, communication channels, and attributes of the innovation on the adoption of tilapia aquaculture. Importantly, this research can inform small-scale aquaculture development policies and strategies of the Government of Solomon Islands, and other Pacific Island Countries, to ensure the sector contributes to rural food and nutritional security.

Diffusion of innovation

Diffusion of Innovation theory is a conceptual framework that explains how an idea, behaviour, or product, referred to as an innovation, gets adopted and spreads through a social system over time. The theory proposes that adoption behaviour, including the time it takes individuals to adopt an innovation, depends on both the socio-economic characteristics of the individual and the attributes of the innovation (Padel 2001; Pannell et al. 2006; Rogers 2003). The theory suggests that socio-economic characteristics of the adopter, along with their personal values and communication behaviour will affect the time taken to adopt the innovation, relative to other members within a social system (e.g. their innovativeness). Moreover, the way in which information about the innovation is communicated to potential adopters (e.g. mass or interpersonal) can also affect adoption. As such, the theory recognises the potential role and influence of change agents such as extension or program officers (Rogers 2003). The attributes of the innovation, which affect the rate of adoption, include its relative advantage, compatibility, complexity, trialability, and observability. Diffusion of Innovation theory, therefore, provides a useful heuristic for this study in that it provides a holistic view of the innovation adoption process.

While the majority of diffusion research has been conducted in the agricultural sector (Glendinning et al. 2001; Kuehne et al. 2017; Peshin et al. 2009), very little has investigated the adoption of innovations in the small-scale aquaculture sector (Blythe et al. 2017). This study explores the potential influence of three components of the Diffusion of Innovation on the adoption of tilapia aquaculture in the Solomon Islands: (1) socio-economic attributes of adopters, (2) communication channels, and (3) attributes of the innovation. Understanding people's perceptions of the innovation (e.g. tilapia aquaculture) and their socio-economic attributes may help explain why rural people have expressed interest in farming tilapia, yet the practice has not been widely adopted (Cleasby et al. 2014). Understanding the relative influence of different communication channels may help to understand why, despite the availability of informational materials (e.g. pamphlets, brochures, posters) and the presence of existing tilapia farmers in the study site, there still seemed to be slow adoption and limited expansion of tilapia aquaculture within the study site (Blythe et al. 2017). Overall, we hypothesise that these three independent variables will have an influence on tilapia aquaculture adoption in rural Solomon Islands.

Materials and methods

Study site

This study was conducted across six tilapia aquaculture clusters (see Fig. 1 caption for definition of clusters) around Auki, the provincial administrative centre of Malaita Province, Solomon Islands (Fig. 1). This site was selected because it comprises the largest cluster of tilapia farmers in the country. Though there may be tilapia aquaculture activities in other provinces, they are infrequent, sparsely distributed, and relatively inaccessible (Sulu et al. 2015).

Malaita Province provides a useful study context because it exhibits geographical, socio-economic, and cultural attributes typical not only of Solomon Islands but the broader Pacific Islands. For instance, 95% of its people are concentrated along the coast (within 5 km off coastal margins), and subsistence fishing and gardening are common livelihoods, while engagement with the formal economy is limited to few income-generating opportunities

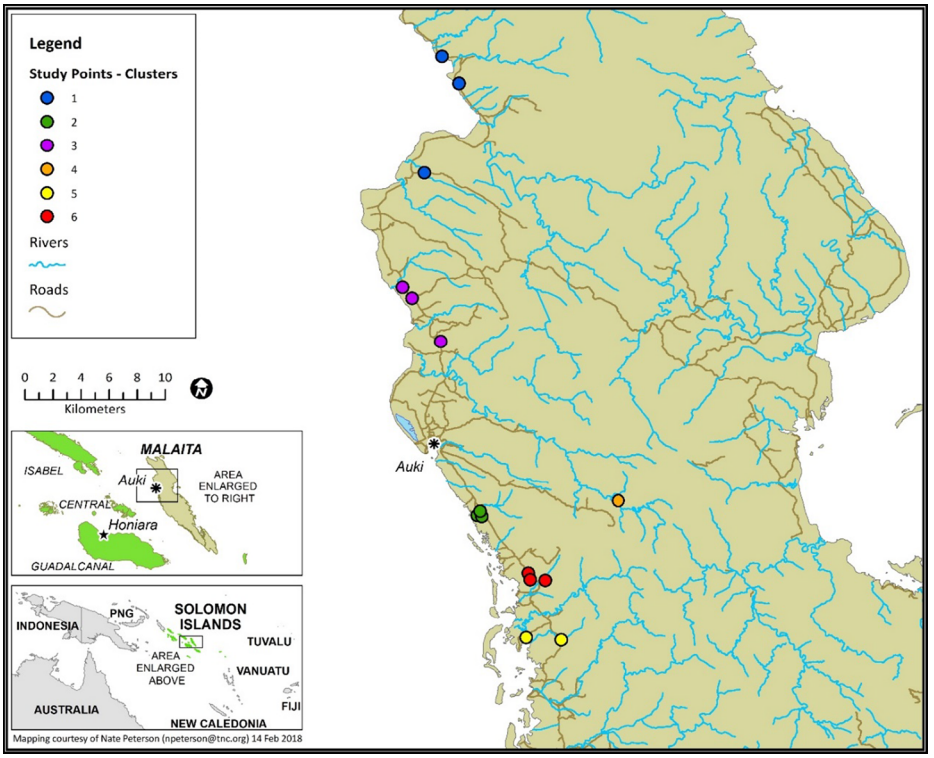

Fig. 1 Map of the study site. The six coloured dots represented the six clusters in which we surveyed respondents (both tilapia aquaculture adopters and non-adopters). "Clusters" here refer to pockets of tilapia farmers distributed throughout the study region. Clusters were devised by placing tilapia farmers within proximity of each other (geographically) in a particular group (herein referred to as a cluster). This enabled ease of accessibility by project officers when delivering extension services to farmers. This strategy was formulated by a previous tilapia aquaculture development project (ACIAR FIS/2010/57) as a means of effective extension service delivery, addressing the problem of farmers geographical spread

(e.g. sale of garden produce, cash-crops, trading of fisheries products, and casual employment) (Connell 1984; Foale et al. 2011).

Lastly, the six farmer clusters were a pre-existing categorisation from an Australian Centre for Agricultural Research (ACIAR) FIS/2010/057 project, which involved the lead author of this paper. The project was implemented by WorldFish and the local Ministry of Fisheries and Marine Resources from 2011 to 2015 and supported collaboration with farmers to develop a mechanism for inland-based aquaculture, based on the local exotic Mozambique tilapia (*Oreochromis mossambicus*). After the project ended, it left behind an informal network of farmers still farming tilapia in homestead ponds, with the inclusion of some new farmers (personal communication; Sulu et al. 2015). Although the number of these tilapia farmers have fluctuated over the years (see Harohau et al. 2016), it provided the ideal site for this study.

Participant selection

Non-probability sampling strategies were used to identify participants for the survey (Ritchie et al. 2013). We characterised our sample population into two groups: tilapia aquaculture

adopters and non-adopters. Tilapia aquaculture adopters were defined as individuals who are active tilapia farmers or may have attempted tilapia aquaculture before but have discontinued or shifted to other livelihood activities. In contrast, non-adopters were those who have never pursued further with the activity.

Purposive sampling was used to achieve a quota sample of 40 tilapia aquaculture adopters and 40 non-adopters. This quota is estimated to represent 69% and 90% of the study site population of each group respectively (Harohau et al. 2016).

Data collection

Data were obtained through face-to-face surveys with individual tilapia aquaculture adopters and non-adopters at their respective dwellings in the six clusters. The survey questions were informed by Diffusion of Innovation theory, whereby specific independent variables used in our analysis were derived from three components of the theory: socio-economic attributes, communication channels, and attributes of the innovation. Data collected included a mixture of nominal, ordinal, and scale level of measurement.

Surveys were conducted face-to-face from 16 May to 21 June 2017 in Solomon Islands *Pidgin* (local language) and were administered by the lead author and a trained field assistant—both fluent in the local language. Participants were surveyed depending on their availability, willingness, and consent to be interviewed that day. Each survey lasted between 35 and 70 min.

Data analysis

Survey data were collated in Microsoft Excel™ software, before being exported into the SPSS statistical package (versions 24 and 25), coded into respective levels of measurement (e.g. nominal, ordinal, scale) for exploratory (descriptive statistics) and the classification tree analysis. A brief description of the specific variables measured and analysed is provided in Table 1.

For the data coded in SPSS, we then used classification tree analysis to explore the relationships between our predictor variables and our dependent variable (adoption or non-adoption). We opted to use classification tree analysis because our dependent variable was binary, and because of its flexibility in exploring both categorical and numeric data, and ability to do data description and predicting patterns (De'ath and Fabricius 2000; Loh 2011). It does not necessarily demand normality and homogeneity of variance between variables, and it facilitates multiple variable interactions. With its recursively partitioning of data thus yielding a set of outcomes presented graphically, it ensures an easy interpretation of the output data set (De'ath and Fabricius, 2000; Loh, 2011).

Results

Descriptive analysis

Socio-economic attributes

The descriptive analysis showed that both groups of farmers (tilapia aquaculture adopters and non-adopters) supported an average of six to seven people in their households, were all male,

Table 1 The three categories informed by Diffusion of Innovation and brief descriptions of their specific independent variables measured

Broad category	General variables	Specific independent variables	Description	Measurement scales
Socio-economic attributes	a. Socio-economic attributes	Age, marital status, household size, material styles of life, literacy level, education, leadership role, land ownership, household subsistence level, number of meals households consumed/day. Total number of household livelihood activities, number of activities for food, activities for income, household weekly income, household weekly expenditure	Material styles of life included the household assets (e.g. radio, generator, solar, transport). Using PCA, this was reduced to two components, basic and high material styles of life (explained by 52% and 21% of total variance respectively) which was used for further analysis. Household subsistence level was measured by the percentage of food locally produced and consumed by household (as opposed to sold for income). Number of meals household consumed/day measures household food security level. Also measured is the total activities household derive their food and income from (quite a number of livelihood activities overlap in this regard, e.g. can be for food or income).	Age, material styles of life, household size, household subsistence level, number of meals consumed/day, total number of livelihood activities, number of activities for food and income, household weekly income and expense (Scale) Marital status, literacy level, leadership, land ownership (nominal) Education, (ordinal)
Communication channels All variables (nominal)	a. Communication channel b.	Communication/information source	a. Word of mouth, written form, farm demonstration, others b. Relatives, lead farmers, friends, project officers, and others.	In total, four communication channels and five information sources were proposed to be used in the study sites.
Attributes of innovation	a. Relative advantage[1] b. Complexity[2] c. Compatibility d. Observability	a. Relative benefits of tilapia farming b. Why tilapia farming was not broadly adopted c. If tilapia farming violates custom norms, and if it imposes additional burden to existing livelihood demand. d. Have you observed benefits from tilapia farming?	For relative advantage and complexity, see explanation below detail. For compatibility, a 3-point scale of the level of agreement was used. For observability, a binominal response of "yes" or "no" was used if respondents observed tilapia farmers benefiting.	Relative advantage, complexity, and observability (nominal) Compatibility (ordinal).

[1] Relative advantage was derived from collation of qualitative responses from the question that looked at the benefits observed from tilapia farmers/farming

[2] Similarly, complexity was derived from qualitative responses from the question that looked at reasons why tilapia farming was not taken up by potential, aspiring farmers

Here, responses were generally collated into common themes, and only those responses that define relative advantage and complexity of tilapia farming (following Blythe et al., 2017) had their frequencies totaled to represent relative advantage and complexity in descriptive analysis and SPSS as two independent variables

and engaged in between four to five livelihood activities (Table 2). Other attributes differed between the two groups of farmers. For instance, tilapia aquaculture adopters were older, had more formal education, higher income, and literacy, were more often married, and held leadership positions. In contrast, non-adopters had higher material styles of life, owned more land, and were more subsistence oriented.

Communication source and channel

Of the five communication sources (Table 2), *relatives* were the most common source across both tilapia aquaculture adopters and non-adopters. For tilapia aquaculture adopters, relatives were followed by lead farmers and extension officers respectively, then friends, followed by others (e.g. tilapia aquaculture activities observed outside of the province). For non-adopters, relatives were followed by lead farmers, extension officers, then friends followed by others.

For the channel by which tilapia aquaculture information was communicated, the majority of tilapia aquaculture adopters and non-adopters relied on *word of mouth*. This was followed by farm demonstration, written forms (e.g. pamphlets, posters), then others (e.g. workshops, observe others) across both groups of farmers.

Attributes of the innovation

The majority of farmers in both groups (95%) perceived tilapia aquaculture to be highly compatible with local norms (Table 2). However, only 50% of tilapia aquaculture adopters and 58% of non-adopters considered tilapia aquaculture to be compatible with their existing livelihood demands.

Tilapia aquaculture had low relative advantage as indicated by both groups (degree to which it was perceived better than similar activity/ or one it supersedes), low complexity (degree by which tilapia aquaculture was difficult to understand or implement), and was slightly more observable (degree by which tilapia aquaculture and associated benefits were visible to others) to non-adopters, than to adopters.

Classification tree analysis

Classification tree analysis was performed to explore the relative influence of the independent variables (Table 1) on tilapia aquaculture adoption and non-adoption. Age showed the highest likelihood of influencing the adoption of tilapia aquaculture, according to the model (Fig. 2). Age was followed by the subsistence level of households (measured by the percentage of food produced and consumed by households) and then material styles of life. Age was split into $\leq$ 57 (young) and $>$ 57 (older) years, at an improvement level of 0.050. Though more tilapia aquaculture adopters ($n = 9$) than non-adopters ($n = 1$) were observed in the $>$ 57 age category, this did not match the high number of both tilapia aquaculture adopters and non-adopters in the $\leq$ 57 age category. Thus, caution should be taken when interpreting this output, in that though there is a possibility that tilapia aquaculture adopters maybe older, the majority still fell into the young age category. Moreover, this result may also be indicative of a broader demographic trend of relatively fewer people over the age of 57.

The young age category was further split by household subsistence level at improvement 0.043, into less subsistence-oriented households ($\leq$ 60%) and more subsistence-oriented ($>$ 60%). Here, tilapia aquaculture adopters were likely to be less subsistence-orientated. For the

Table 2 Mean and frequency of independent variables of the independent variables under socio-economic characteristics, communication, and attributes of innovation

Category	Variables	Adopters ($N = 40$)	Non-adopters ($N = 40$)
		Mean ± (SE)	
Socio-economic attributes	Age (years)	45 ± (2.5)	40 ± (1.9)
	Household size (# of people)	6 ± (0.5)	7 ± (0.7)
	Subsistence level (%)	55.3 ± (4.0)	62 ± (4.7)
	Number of livelihood activities	5 ± (0.2)	4 ± (0.2)
	Weekly household income (SBD)	$1134.2 ± (242.8)	$895.5 ± (142.4)
	Weekly household expenditure (SBD)	$88.4 ± (22.8)	$108.5 ± (34.3)
	Basic material style of life	0.1 ± (0.2)	−0.1 ± (0.2)
		Frequency (%)	
	Sex (male)	100	100
	Marital status (Married)	95	88
	Literacy level	83	75
	Education	88	83
	Leadership positions	58	53
	Land ownership	75	85
Communication channels	Word of mouth	63	80
	Farm demonstration	55	33
	Written form (e.g. pamphlets)	25	10
	Others	8	0
Communication Sources	Lead farmers	25	43
	Project/extension officers	25	8
	Friends	5	5
	Relatives	55	45
	Others	5	5
Attributes of innovation	Relative advantage	5	13
	Compatibility		
	I. With socio-cultural norms	I. 95	I. 95
	II. With existing livelihood demand	II. 50	II. 58
	Complexity	38	25
	Observability	48	58

less subsistence-orientated households, material styles of life (MSL) resulted in two terminal nodes: higher MSL (≤ -1.03) (i.e. less basic) and more basic MSL (> -1.03). This suggests that tilapia aquaculture adopters were more likely to have basic MSL than non-adopters. Cautiously, no tilapia aquaculture adopters ($n = 0$) and a minimal number of non-adopters ($n = 5$) were in the higher MSL category compared with a larger number of both in the basic MSL category. As such, there is a likelihood that those members of the community who have higher MSL will be non-adopters, even though a larger proportion overall are in the basic MSL category. Finally, more subsistence-oriented households were further split by age (at improvement = 0.031) into two categories: ≤ 39.5 (young) and > 39.5 (older/mature aged). Hence, in more subsistence-orientated households, there is a propensity for non-adopters to be younger than tilapia aquaculture adopters.

Discussion

With food insecurity predicted to increase across Pacific Island Countries like Solomon Islands, tilapia aquaculture has been proposed a means to complement coastal fisheries (Amos et al. 2014; Pickering 2010). Despite tilapia aquaculture's potential contributions to

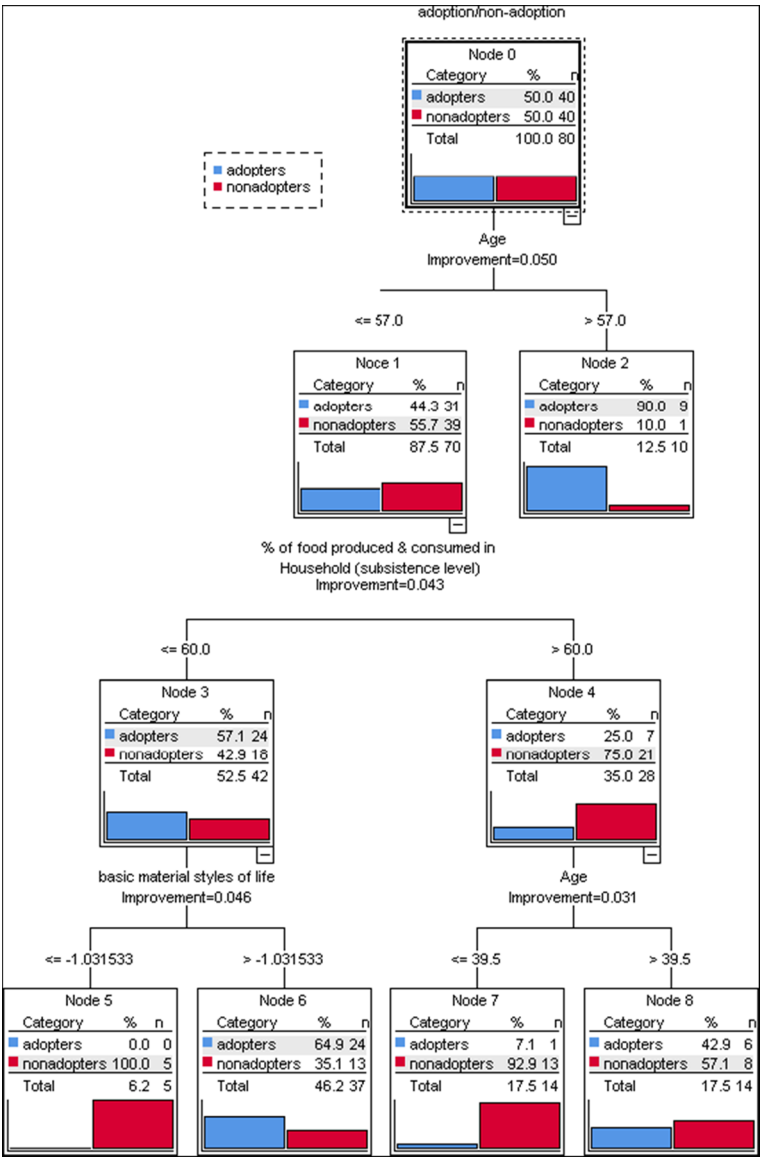

Fig. 2 Classification tree of the influence of socio-economic attributes, communication channels, and attributes on tilapia aquaculture adoption and non-adoption. The four splits in the model show the variables that determine the distribution of the dependent variable as displayed in the subsequent nodes. The misclassification (Resubstitution) risk for the model was 26.3% (std. error 0.049). Criteria were set to 10 sample folds, with growth limit set at 10 for parent node and 5 for child node

food and nutritional security, the relatively low adoption has limited its contributions to date. One of the recognised obstacles for aquaculture development is the limited understanding of the social factors affecting interests and capabilities of rural farmers to adopt the activity in their different contexts (Slater et al. 2013). Using the Diffusion of Innovation Theory, our study looked at the influence of socio-economic attributes, communication channels, and

attributes of innovation on the adoption of tilapia aquaculture in a rural Solomon Islands context. Our results showed tilapia aquaculture adopters and non-adopters differed in most of their socio-economic attributes, where adopters tended to be older, less subsistence-oriented, and with lower material styles of life than non-adopters. Next, both groups received the majority of their information about tilapia aquaculture through informal channels, including relatives and via word-of-mouth, as opposed to more formal channels such as extension agents and written pamphlets. While the innovation was seen as compatible with socio-cultural norms and livelihood demands, its relative advantage and observability in comparison with other livelihoods activities were perceived as low. The classification tree model showed socio-economic attributes (age, subsistence level of households, and material styles of life) to be the most influential variables on tilapia aquaculture adoption. These finding have important implications for rural tilapia aquaculture development across the PICs, which are discussed below.

First, the finding that socio-economic attributes influenced adoption was consistent with other studies which found similar socio-economic factors (e.g. farm size, wealth, age, access to credit) to influence the adoption of comparable agriculture and fish farming technologies (Akudugu et al. 2012; Blythe et al. 2017; Diedrich et al. 2019; Mandima 1995; Pandey and Upadhyay 2012; Sileshi et al. 2019). These studies argued that consideration of socio-economic factors was vital for successful implementation and uptake of innovations into rural communities. In our study, age was identified as having the strongest influence on tilapia aquaculture adoption and non-adoption. This was in contrast to studies that found younger farmers were most likely to adopt innovations, due to their risk-taking nature and longer planning prospects (Asfaw and Neka 2017; Donkor et al. 2019; Kapanda et al. 2003; Ngoc et al. 2016; Ofuoku et al. 2008). Despite this, studies by Blythe et al. (2017); Mignouna et al. (2011); Uhunamure et al. (2019); and Wetengere (2011) showed the contrary, where older farmers were more likely to be adopters. The studies cited that older farmers tend to spend more time at home giving them free time to adopt, were more experienced, and preferred low-maintenance innovations. Furthermore, some studies have also shown that age does not influence adoption (Akudugu et al. 2012; Tenge et al. 2004). These varied results imply that influence of age on adoption is highly contextual and may depend on the type of innovation. In this current study, age also featured as having a weaker influence on tilapia aquaculture adoption and non-adoption at the terminal node of the model, where individuals younger than 39.5 years old in subsistence-oriented households were less likely to adopt. This may be because younger individuals frequently move in and out of their villages, and are more inclined to undertake better income-generating opportunities than tilapia aquaculture (Wetengere 2011). Age, therefore, may not possess a consistent relationship with adoption across contexts.

Second, descriptive analysis showed tilapia aquaculture adopters were all male, which suggests that adoption (and therefore its associated benefits) may be gendered and not reaching marginalised groups (e.g. women and children). This highlights an important relationship between equity and adoption that can potentially constrain fair distribution of benefits from tilapia aquaculture, while also demonstrating the unique needs of vulnerable members of the community (Haider et al. 2018; Kruijssen et al. 2018; Makate et al. 2019). Consideration of equity is not only essential in identifying farmers' capacity to adapt and benefit from tilapia aquaculture but also to avoid small-scale aquaculture development interventions running the risk of further exacerbating marginalisation of poor farmers and households (Diedrich et al. 2019). Overall, this issue of equity calls for a more in-depth understanding of the socio-economic attributes of aspiring farmers when planning small-scale aquaculture development

(Belton and Little 2011; Lado 1998; Morse and McNamara 2013; Munasinghe et al. 2010; Naegel 1995; Senff et al. 2018).

Third, the model showed that respondents who were less subsistence-oriented and who had basic material style of life were likely to be tilapia aquaculture adopters (note, though the relative influence of this variable and the sample distribution on this split suggests this result maybe negligible). These specific socio-economic attributes (less subsistence, with basic MSL), in addition to the dynamics previously explained, are important to consider because they may also influence time available and motivation of a farmer to adopt tilapia aquaculture. For instance, farmers in households who spend less time on subsistence activities may have more time to dedicate to additional livelihood activities (e.g. tilapia aquaculture), whereas farmers in better-off households may be content with what they currently have thus have less time or motivation to adopt a new livelihood activity. This result is consistent with findings by Diedrich et al. (2018) and Asfaw and Neka (2017) in their respective studies of sportfishing tourism in Papua New Guinea and adoption of soil and water conservation practices in Ethiopia. Further research may be needed to further establish any significance between time, motivation, and adoption of competing livelihood activities. It is therefore important for policymakers, extension service officers, and development agencies to be conscious of these potential socio-economic attributes in order to tailor assistance accordingly to rural farmers. This may require a collaborative effort from all relevant stakeholders to minimise prominent contextual barriers to adoption such as time available to invest in other livelihood activities, or possible diversion of physical assets investments from tilapia aquaculture to other viable livelihood activities (Curry et al. 2015; Slater et al. 2013).

Lastly, the popularity of relatives (as a communication source) and word-of-mouth (as a communication channel) demonstrated a greater reliance on interpersonal channels, mostly between people closely related or with similar backgrounds (e.g. either through kinship, social status, geographical locality, same dialect) (Barnes et al. 2016; Hoa et al. 2009; Rogers 2003). In this study, this may be because many rural farmers are more comfortable and confident conversing with those similar to them (e.g. relatives), but not so with those dissimilar to them (e.g. change agent, opinion leader). Rogers (2003) coined this the homophilous aspect of communication networks, where people with similar backgrounds not only frequently communicate with each other but do so effectively because of their shared issues and goals. Our finding was consistent with a number of studies that highlight communication about innovations occur within close social networks (Bandiera 2006; Kiptot et al. 2006; Mittal and Mehar 2016; Nakano et al. 2018; Superio et al. 2018; Vishnu et al. 2019). However, it was contrary to studies by Adolwa et al. (2012) and Nyambo and Ligate (2013) who highlighted that, with the adoption of soil fertility management and cashew production in Western Kenya and Tanzania respectively, mass-media forms of communication (especially radio) were mostly relied upon for effective communication. Our finding again reinforces why it is essential for stakeholders to pay closer attention to the local context, in this case by recognising and appreciating the locally appropriate sources and channels for communicating tilapia aquaculture information. In this way, they can build on or utilise these locally appropriate communication attributes for effective dissemination of tilapia aquaculture information, which could lead to wider adoption. However, we argue here that these locally appropriate communication channels alone may be inadequate for longer-term sustainability of tilapia aquaculture by adopters. Technical assistance and extension services are equally vital to ensure the spread of sustainable small-scale aquaculture, because although relatives may be a go-to source for tilapia aquaculture information, they may only hold basic awareness knowledge and not principles knowledge. The

latter is an important form of social capital not only for sustaining tilapia aquaculture over time but also ensuring its tangible impact on food and nutrition security (Blythe et al. 2017). Studies by Adesina et al. (2000); Baticados et al. (2014); Hudson et al. (2016); Ofuoku et al. (2008); Tenge et al. (2004); and Wetengere (2011) are few of many studies that supported the need for extension services in promoting technological adoption and its sustainability (both in aquaculture and agriculture). Our results also pointed out that while tilapia aquaculture was less complex and compatible with the socio-cultural norms and livelihood demands of farmers, it had low relative advantage and observability. Although not established by our findings, these weaker attributes of tilapia aquaculture (low relative advantage and observability) may have contributed to tilapia aquaculture adopters shifting to other economically viable activities, after practicing the activity for some time (reported by Harohau et al. 2016). Addressing these weaker attributes of tilapia aquaculture can therefore be vital to ensure the innovation has the potential for wider adoption.

While our study identified novel influential variables for tilapia aquaculture adoption in a rural setting in Solomon Islands, there are several limitations worth highlighting. First, despite the classification tree model identifying socio-economic variables as most influential on tilapia aquaculture adoption, this does not necessarily suggest the other variables (attributes of innovation and communication) were unimportant to tilapia aquaculture adoption. Rather, the outcome may be attributed to the nature of the classification tree analysis, which modelled the influences of the sets of independent variables on adoption, based on the data's underlying distribution properties (Lo et al. 2015). Hence, the recursive partitioning of the variables into homogenous groups may mask the importance of other independent variables that would otherwise be relevant once considered alone (Loh 2011). Second, although our study was able to show some factors influencing tilapia aquaculture adoption, it may not cover all possible factors potentially influencing the activity's adoption in the local context. There may be other variables less related to our theoretical framework that could be measured to observe their influence on tilapia aquaculture adoption (e.g. institutional factors). Future research can expand on this, and look into other potential variables. Finally, our data were collected well after adoption decisions were made by farmers, hence, may be subjected to potential limitations of recall bias. As Meyer (2004) stated, farmers' ability to accurately recall past events may be limited and subjected to various biases. To address this potential limitation in future studies, data could be collected at multiple times through longitudinal studies (Meyer 2004).

Conclusion

This study aimed to understand the factors influencing the adoption of tilapia aquaculture in a rural Solomon Islands context using the theoretical framework of Diffusion of Innovation. The study contributes to knowledge on small-scale aquaculture adoption, especially from a Pacific Islands perspective where limited studies (to the knowledge of the authors) have explored before. The results suggested that socio-economic attributes were more influential than attributes of the innovation and communication channels on the adoption of tilapia aquaculture. Specifically, tilapia aquaculture adopters tend to be older, male, less subsistence-oriented, with basic material styles of life. Our analysis also showed that relatives and word-of-mouth were the most common forms of communication in our study context. While tilapia aquaculture was compatible with socio-cultural norms and livelihood demands of farmers, it had low relative advantage and observability.

Our findings suggest that interventions pertaining to tilapia aquaculture development in the rural areas must prioritise understanding the socio-economic attributes of rural farmers and how these attributes influence adoption. This includes consideration of the issue of equity and the ability to adopt new innovations and the associated distribution of benefits. This is vital in identifying farmers' capacity to adopt and benefit from tilapia aquaculture, and at the same time avoid small-scale aquaculture interventions that run the risk of further marginalising poor farmers. Our findings also support the need to recognise locally appropriate channels of communication for effective dissemination of tilapia aquaculture information.

Taken together, our results suggest that for tilapia aquaculture to contribute to food and nutritional security in Solomon Islands, and across the Pacific, governments, development agencies, and non-governmental organisations will need to continue investment in research and programs that engage closely with local social dynamics that shape its adoption by rural households.

Acknowledgements We would like to acknowledge all the individuals from Solomon Islands who participated in this research. Also, WorldFish, Solomon Islands office is duly acknowledged for field and logistical support during data collection for this paper. Special thanks to Tracy MacKeracher for assistance in draft review, Brett Mumae for assisting with data collection in the field, Nate Peterson for creating the study map, and Peter Gatenby for proof reading.

Funding information The research was made possible through funding support from the Australian Centre for International Agricultural Research, through the John Allwright Fellowship Scholarship Scheme, and both the James Cook University Postgraduate Research Fund and Postgraduate Research Scholarship. This work was undertaken as part of the CGIAR Research Program on Fish Agri-Food Systems (FISH) led by WorldFish. The program is supported by contributors to the CGIAR Trust Fund.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval Because this study involved human subjects, a human ethics application ID H6870 was approved by the James Cook University Human Research Ethics committee on the 1/03/2017 before this study was carried out. This article does not contain any studies with animals performed by any of the authors.

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