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Stepping Up versus Stepping Out: On the outcomes and drivers of two alternative climate change adaptation strategies of smallholders

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ABSTRACT

Which of the two climate change adaptation strategies – adjusting or improving farming (defined as Stepping Up) versus reducing or exiting farming (defined as Stepping Out) – provides better developmental outcomes for smallholder farmers? Are the drivers of these two strategies different? Do the outcomes and drivers vary according to farmland holding size? We investigated these unanswered questions, inspired primarily by a widespread but unverified suggestion that stepping out of farming can be a better option for smallholders. We utilised recent survey data from over eight hundred smallholder households located in climatic hazard-prone areas in Bangladesh. We applied a holistic Driver-Strategy-Outcome analytical framework and rigorous statistical methods, including index-based data aggregation, and Structural Equation Modelling with 'mediation' and 'moderation' analyses. Contrary to widespread speculations, we found that Stepping Out had a large negative effect on smallholders' livelihood Outcomes; while Stepping Up had a moderate, but positive effect. The natural-environmental Drivers of Stepping Up and Stepping Out were similar; however, the psychological-institutional Drivers of each differed, with the same factor acting as a driver for one strategy whilst as a deterrent for the other. We found significant 'mediatory' effects of both the adaptation Strategies on Outcomes as well as significant 'moderation' effects of farmland holding size on the Drivers and Outcomes, with the positive effect of Stepping Up observed for smallholders owing lands of <2.5 acres only. We call for relevant policies and interventions to exercise caution in promoting smallholders' exit from agriculture, and to adopt appropriate mitigating measures to manage such a transition. Moreover, smallholder agricultural development initiatives should not discount even the 'smallest of smallholders' and support them through 'diverse and complementary innovations' as well as 'tailored' institutional support services, especially for those living in proximity to hazard hotspots.

1. Introduction

It is widely recognised that over 475 million of the world's smallholders play a significant role in global food security and poverty alleviation (HLPE, 2013; IFAD & UNEP, 2013; Lowder et al., 2016). However, such developmental outcomes are in jeopardy due to the adverse impacts of global climate change, including climatic variability and extremes (Cohn et al., 2017; Morton, 2007; Vermeulen et al., 2012). This is particularly concerning as smallholders tend to be resource-poor; cultivate marginal lands; and have inadequate access to technical, financial, and institutional services – thus being more vulnerable to global climate change (Cohn et al., 2017; Harvey et al., 2014; HLPE, 2013; Morton, 2007; Vermeulen et al., 2012). This realisation has triggered a significant body of research focusing on the measures that smallholders adopt in response to climatic changes, so that their adaptation could be better supported through planned interventions (Burnham & Ma, 2018).

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Numerous studies have identified a myriad of adaptation practices in several continents of the developing world (see Harvey et al., 2018 for Central America; Menghistu et al., 2020 for Sub-Saharan Africa; and Shaffril et al., 2018 for Asia). These include on-farm practices – e.g., changing planting and/or harvesting times, cultivating resistant varieties, crop diversification, adopting agroforestry, adjusting agrochemical use, adopting new soil and/or water management practices, and buying insurance products – as well as off- or non-farm practices – e.g., engaging in off-farm jobs or businesses, migration, and even reducing or exiting farming (Aryal et al., 2020; Khan et al., 2020; Kumasi et al., 2019; Menghistu et al., 2020; Nganga et al., 2016; Rahut & Ali, 2017; Shaffril et al., 2018; Shukla et al., 2019). Studies have also identified numerous drivers of these practices (Aryal et al., 2020; Kabir et al., 2017; Burnham & Ma, 2018; Khan et al., 2020; Menghistu et al., 2020; Nganga et al., 2016; Paik et al., 2020; Rymbai & Sheikh, 2018; Sadiq et al., 2019; Samuel & Sylvia, 2019) as well as the impacts of their adoption (see Hansen et al., 2019 for a review; see also Bailey et al., 2019; Rahut & Ali, 2017). Yet, some crucial questions remain: Which of the two types of adaptation strategies – agricultural versus non-agricultural – provides better developmental outcomes for smallholders? Are the drivers of these strategies different? Do the outcomes and drivers vary according to farmland holding size?

These questions seem crucial due to widespread interest amongst notable international donors and development practitioners (e.g., DFID, 2015; FAO, 2017; FAO, 2018; Global Donor Platform for Rural Development, 2019; IFAD, 2018; Steinbach et al., 2016; Thornton et al., 2019) as well as academics (Hansen et al., 2019; Stringer et al., 2020) in these two alternative adaptation pathways. Although terminologies vary, the agricultural versus non-agricultural dichotomy is discernible in their discourses, with a central theme being that, rather than continue engaging with agriculture, a better adaptation strategy for smallholders might be to 'step out' of agriculture.

Such views appear to be contentious (Agarwal & Agrawal, 2017; Kerssen, 2015; La Via Campesina, 2009; Li, 2009; Taylor, 2015). Advocates of the food sovereignty movement, for example, label such a proposition, in Farshad Araghi's term, as 'Global Depesantization' (Araghi, 1995) and even calls for ex-farmers to return to farming for the so called 're-peasantization' of the countryside (see Kerssen, 2015; La Via Campesina, 2009). Likewise, the proposition for smallholders to exit agriculture in the 2008 World Development Report has been criticised (see Li, 2009). The advancement of this long-stating and contentious proposition for climatic change adaptation has thus faced disapproval (Taylor, 2015). The main opposing argument is that the job markets in developing countries are often ill-equipped to absorb such extra workforce and those exiting farming often have low education and skills, which may prevent them from finding decent employments in the non-farm sector (Agarwal & Agrawal, 2017; Taylor, 2015). Therefore, improving agriculture, rather than leaving it, would be a better option for alleviating smallholders' poverty.

Both sides of the debate, however, lack adequate empirical evidence, especially based on smallholders' own perspectives and real-world experiences of dealing with climatic changes. Whilst studies on the impacts of 'agricultural' adaptation practices are abound (e.g., see Hansen et al., 2019 for a review), that on 'non-agricultural' adaptation, especially farm-exit, is deficient. Moreover, studies found on the latter (e.g., Imai et al., 2015; Rahman & Mishra, 2020; Zereyesus et al., 2017) are usually not in a climate change context.

As regards adaptation drivers, studies have identified numerous factors; however, predominantly about the drivers of 'agricultural' adaptation practices (Aryal et al., 2020; Kabir et al., 2017; Burnham & Ma, 2018; Khan et al., 2020; Menghistu et al., 2020; Paik et al., 2020; Rymbai & Sheikh, 2018; Sadiq et al., 2019; Samuel & Sylvia, 2019). The few studies (Nganga et al., 2016; Rahut & Ali, 2017) found on the drivers of non-agricultural practices suffer from notable shortcomings, including an omission of farm-exit; analysing non-farm participation as one binary (yes/no) variable (without giving details about the associated non-farm practices); and non-inclusion of climatic factors as drivers. This gap in the literature raises an uncertainty as to whether the drivers of agricultural and non-agricultural adaptation are different.

Existing smallholder adaptation literature is also characterised by notable methodological limitations – a key one being a lack of 'aggregation'. Researchers have typically investigated the drivers and impacts of 'individual adaptation practices' (e.g., for drivers, see the studies by Khan et al., 2020 in Pakistan; Nganga et al., 2016 in Ethiopia; Paik et al., 2020 in Vietnam; Rymbai & Sheikh, 2018 in India; Sadiq et al., 2019 in Ghana; and for impacts of adoption, see Bailey et al., 2019 in Swaziland; Hansen et al., 2019 in multiple countries; Rahut & Ali, 2017 in Pakistan). Such an analytical approach contradicts with the observation that a smallholder does not adopt a single practice (e.g., changing planting time) in isolation (Khanal & Wilson, 2019). Therefore, relating such individual practices with complex livelihood outcomes – e.g., poverty alleviation or food security (Bailey et al., 2019; Rahut & Ali, 2017) – can be problematic. Although some researchers (e.g., Khanal & Wilson, 2019; Tesfahun & Chawla, 2020) studied adaptation as index variables, those indexes included a mixture of on-farm and off-farm activities, thus masking potential dichotomies between these two categories.

Another important methodological limitation is a lack of analytical 'holism'. In a climate and development context, 'adaptation' is premised on the assumption that a climatic change (e.g., increased floods) will have an adverse effect on development outcomes (e.g., food security) and that the adoption of an adaptation practice (e.g., a flood-resistant variety) could offset such an adverse effect. Adaptation is thus assumed to have a 'mediatory effect' between climatic changes and outcomes. Validation of such an assumption through a 'holistic' analytical approach – examining the 'ClimateChange → Adaptation → Outcome' links as a whole – however remains scant.

The third methodological limitation concerns a lack of disaggregated analysis of adaptation drivers and outcomes according to smallholders' landholding sizes. Smallholders' 'small' farm size is commonly implicated as a barrier to 'stepping up' (adjusting or improving agriculture) and thus a justification for 'stepping out' (DFID, 2015; Global Donor Platform for Rural Development, 2019; Stringer et al., 2020). In general, a smallholder's farm size is defined as falling within the range of 0.24–5.0 ha (Rapsomanikis, 2015); however, no study provides a precise estimate of the problematic farm size within this range.

Our aim in this paper is to address these knowledge gaps, specifically to determine: (i) the relative effects of agricultural (stepping up) versus non-agricultural (stepping out) adaptation strategies on the developmental outcomes of smallholders; (ii) if the drivers of these strategies differ; (iii) if adaptation strategies mediate the links between adaptation drivers and outcomes; and (iv) if adaptation drivers and outcomes vary according to smallholders' farmland holding size. For this research, we utilise recent survey data from smallholder households located in climatic hazard-prone areas in Bangladesh – a country widely recognised as one of the most vulnerable to global climate change (World Bank, 2013; IPCC, 2007), with documented evidence of smallholder adaptations (Aryal et al., 2020; Islam et al., 2020). Additionally, we apply a holistic, integrated framework and new methods, including index-based data aggregation, and Structural Equation Modelling with 'mediation' and 'moderation' analyses.

The remainder of this paper is structured as follows: Conceptual Framework and Hypotheses (Section 2), Data and Methods (Section 3), Results (Section 4), and Discussion and Conclusions (Section 5).

2. Conceptual framework and hypotheses

We conceptualise that smallholders' adaptation Strategies, Drivers, and Outcomes are interlinked, and therefore, it is better to study these as a whole. In our framework (Fig. 1), we place adaptation Strategies at the middle – linking adaptation Drivers on the one end and adaptation Outcomes on the other. We assume that this entire chain of relationships is embedded within wealth-based economic structures, typified by farmland ownership, in an agrarian society. This framework is based on social-ecological systems thinking and draws on the sustainable livelihoods, resilience, and vulnerability literature (e.g., Adger et al., 2013; IPCC, 2007; Scoones, 1998; Serrat, 2017). Below we elaborate on the concepts in the framework and propose our research hypotheses.

2.1. Strategies

Instead of using everyday languages like 'agricultural' versus 'non-agricultural' or 'on-farm' versus 'off- or non-farm', we use 'Stepping Up' (SU) versus 'Stepping Out' (SO) (Dorward et al., 2009). The SU-SO typology has a solid theoretical grounding (Pritchard et al., 2017) and is used widely by the development community (e.g., DFID, 2015; FAO, 2017; FAO, 2018; Global Donor Platform for Rural Development, 2019) and academics (e.g., Hansen et al., 2019). Neither of these terms, however, is consistently defined, interpreted, or operationalised. Broadly, SU could be defined as adjusting or improving farming through new investments and activities, whilst SO as reducing or exiting farming to engage in non- or off-farm activities. Both concepts denote departure from 'Hanging In' (HI) – a situation when a household is concerned with maintaining its current assets and activities in the face of shocks and stresses.

The indicators used in interpreting or investigating SU and SO vary considerably. While, DFID (2015), for instance, almost equates SU with commercialisation (agri-business development), others (Scoones et al., 2012; Thornton et al., 2018; Tittonell, 2014; Valbuena et al., 2015; Wang et al., 2019) have used a range of indicators: intensification and use of agricultural inputs, e.g., seeds, fertiliser, and insurance (Hansen et al., 2019; Thornton et al., 2018); buying or cultivating more lands (Hansen et al., 2019; Valbuena et al., 2015); diversifying agriculture (Hansen et al., 2019; Valbuena et al., 2015); semi-commercialising or commercialising farming (Hansen et al., 2019; Tittonell, 2014) and investing in productive assets (Wang et al., 2019). SO indicators included: reduced income from agriculture and/or increased income from non-farm activities, selling off or renting out land, migration, and exit from farming (Hansen et al., 2019; Tittonell, 2014; Thornton et al., 2018; Valbuena et al., 2015). It appears from this literature that SU and SO are multi-indicator concepts, which would require aggregation in their analysis; and that exiting farming is an important, but not the sole indicator of SO.

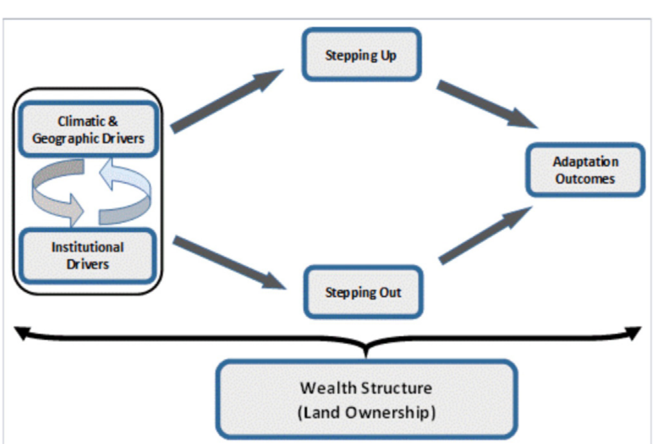

Fig. 1. The conceptual framework of the current study.

2.2. Drivers

Inspired by social-ecological systems thinking, we conceptualise that both 'nature' and 'society' are crucial for understanding the drivers of smallholders' adaptation. Within the former, we consider climatic and geographic factors, whilst within the latter, institutional factors.

We expect smallholders' perceptions of climatic changes to be an important climatic driver. Although this aspect has received less attention in the livelihoods literature (Dorward et al., 2009; Scoones et al., 2012), the link between human psychology and behaviour is well-established (Ajzen, 1991). Many studies have confirmed the effects of smallholders' perceptions of climatic changes on their agricultural adaptation practices (Islam et al., 2020; Khan et al., 2020; Luu et al., 2019; Sadiq et al., 2019; Samuel & Sylvia, 2019). The effects of such perception on non-agricultural adaptation, especially farm-exit, is however unknown.

Drawing on the vulnerability literature (IPCC, 2007) we consider smallholders' 'exposure' (E) and 'sensitivity' (S) (likelihood of damages) to climatic changes as another important driver. However, in line with others (Antwi-Agyei et al., 2012; Islam & Al Mamun, 2020; Smit & Wandel 2006) we consider E and S to be an integrated concept (ES), since damages cannot occur without a household being exposed first. The damages could include: decline in land productivity, destruction of crops, loss of livestock, loss of lives, damage to assets, damage to infrastructure, and disease outbreaks (Islam & Al Mamun, 2020). Such exposure-damages could trigger adaptation, e.g., decline in soil productivity due to salinity intrusion caused by tidal floods could drive SO (Shameem et al., 2014; The Daily Star, 2018; Tittonell, 2014). Death or illness of household members could lead to a household switching its strategy from SU to HI (Valbuena et al., 2015; Scoones et al., 2012). The vulnerability literature, however, has predominantly focused on non-agricultural adaptation, especially out-migration (see review by Kaczan & Orgill-Meyer, 2020); and thus, the role of exposure-damages in SU remains unclear.

Within geographic drivers, we consider households' spatial location to be important. For example, proximity to coasts could increase the likelihood of a household being exposed to climatic hazards (Barbier, 2015; Islam & Winkel, 2017), such as floods and salinity intrusion, which could reduce the fertility and productivity of the household's lands. This, in turn, may drive households to take adaptive measures, e.g., abandoning farming (Shameem et al., 2014) and out-migration (The Daily Star, 2018). However, the effect of such spatial factors on SU remains unknown.

Moreover, drawing on the Sustainable Livelihoods literature (Scoones, 1998; Serrat, 2017), we consider 'institutions' to be important adaptation drivers. We define institutions as both rules and structures (organisations), which could be external or local (Agrawal, 2009; IFAD & FAO 2012; World Bank 2002). External institutions (e.g., government departments) could promote climate change adaptation through policies, information, advice, training, inputs, technologies, incentives, and funding (Agrawal, 2010; Islam & Nursey-Bray, 2017; Wang et al., 2013); whilst, local institutions – such as community groups – could promote adaptation by facilitating collective actions, shaping climate change impacts on communities, shaping community responses, and acting as intermediaries for external support (Adger, 2003; Agrawal, 2010; Khanal et al., 2019). Institutions, however, could also act as barriers to climate change adaptation (Biesbroek et al., 2013; Wang et al., 2013). There can be many institutional drivers, but we consider three drivers commonly identified by numerous studies across countries and continents. These are: contacts with extension institutions, memberships in local groups/organisations, and access to credits (e.g., Arunrat et al., 2017; Nganga et al., 2016; Rahut & Ali, 2017; Sadiq et al., 2019; Samuel & Sylvia, 2019; Tesfahun & Chawla, 2020; Khan et al., 2020). Overwhelmingly, however, previous studies have focused on their positive effects on agricultural, rather than on non-agricultural adaptation.

Based on the above, we hypothesise that all the six drivers included in our study will have significant effects on smallholders' adoption of the SO and SU Strategies discussed in section 2.1 (Hypothesis 1). However, given the gaps in the literature, we do not specify a priori the direction (+/−) of the effects.

According to the livelihoods literature (Scoones, 1998; Serrat, 2017), we also expect the climatic-geographic and institutional drivers to be correlated. However, our aim here is not to test these correlations; rather to use those findings to interpret the hypothesised effects of the Driver-Strategy relationships, wherever applicable.

2.3. Outcomes

The literature is incongruent regarding the indicators of climate change adaptation Outcomes. Studies on 'agricultural' adaptation practices have used various indicators, e.g., improved household nutrition, child nutrition, nutrition quality and diversity, reduced months of food deficits, reduced distress selling of assets, improved calorie intake and diet diversity, improved food security, improved crop yields, increased stability of yields, increased recovery time after extreme climatic events, increased income, production cost saving, increased mobility, and increased resilience (see Hansen et al., 2019 for a review; also see Bailey et al., 2019; Rahut & Ali, 2017). Although crop yield and food security (broadly defined) appeared to be more common, the other indicators were mostly unique to each study, making it challenging to assess the Outcome variable.

We conceptualise 'adaptation outcomes' broadly with 'livelihood outcomes' in the Sustainable Livelihoods literature (Krantz, 2001; Scoones, 1998; Serrat, 2017), which refers to: more income; increased wellbeing; reduced vulnerability; improved food security; more sustainable use of natural resources; securities of nutrition, health, shelter, water, education; community participation; and personal safety. Although such wider focus – transcending agriculture, food, and nutrition – is more relevant to this study, the breadth of these indicators and their varied interpretations (e.g., regarding complex, multifaceted concepts like 'wellbeing', 'vulnerability', and 'resilience') pose methodological challenges. Sustainable Livelihoods methodology, however, encourages researchers to interpret and select these indicators according to local contexts and from the perspectives of households (Scoones, 1998).

According to the conceptualisations in the literature (e.g., Agarwal & Agrawal, 2017; DFID, 2015; FAO, 2017; FAO, 2018; Global Donor Platform for Rural Development, 2019; Hansen et al., 2019; Kerssen, 2015; La Via Campesina, 2009; Li, 2009; Stringer et al., 2020; Taylor, 2015), we expect both SU and SO to have significant effects on smallholders' livelihood Outcomes (Hypothesis 2). However, in the absence of conclusive empirical evidence, we do not speculate a priori the direction (+/−) of such effects.

Regarding the Strategy → Outcome effects, we also expect, in line with the Sustainable Livelihoods literature (Scoones 1998; Serrat, 2017) that both the SO and SU adaptation strategies will 'mediate' the relationship between adaptation Drivers and Outcomes, and thus provide robust evidence of their effects on adaptation Outcomes (Hypothesis 3).

2.4. Wealth

We conceptualise that the Driver → Strategy → Outcome relationships are embedded within wealth-based structures in an agrarian society. Here, we use the term 'wealth' (Hansen et al., 2019) synonymously with the terms 'assets' (Krantz, 2001; Scoones, 1998; Serrat, 2017) and 'resources' (Tittonell, 2014) in the livelihoods literature. However, rather than treating wealth as 'driver' of adaptation, we conceptualise it as a 'moderator', defined as a variable that can alter the relationships between other variables within a system (Little et al., 2007).

Although, the indicators of wealth can be numerous and context-specific, we consider 'farmland ownership' as a proxy indicator for several reasons. Firstly, as mentioned in Section 1, there is an ongoing argument, but a knowledge gap, regarding the size of farmland holding suitable for smallholders' SU (DFID, 2015; Global Donor Platform for Rural Development, 2019; Stringer et al., 2020). To fill this knowledge gap, we want to avoid other indicators of wealth. Secondly, disparities in farmland ownership in developing countries is found highly correlated with poverty, especially in 'land scarce' countries like Bangladesh and India (Moene, 1992; Lipton & Longhurst, 1985). Thirdly, it has a long history of use as a proxy indicator of wealth among rural households in developing countries (e.g., Kaczan & Orgill-Meyer, 2020; Lipton & Longhurst, 1985; WFP, 2017). Finally, in agrarian societies, land is often regarded as an indicator of social status, which in turn, could allow households to access other types of assets, power, and privilege.

Wealth (landholding size being a proxy) could moderate the Driver → Strategy links proposed in Section 2.2. For instance, despite positive psychological orientations towards environmental issues, people may not engage in pro-environmental behaviour (psychology-behaviour gap) due to the so called 'actual behavioural control' factors, of which wealth can be one (Ajzen, 1991; Kollmuss & Agyeman, 2002). Similarly, although poorer people are more likely to live in climatic risk-prone environments and are more susceptible to damages (see Barbier, 2015; Islam & Winkel, 2017; Neumann et al., 2015), they may not be able to take adaptive measures, e.g., out-migration, which requires wealth. Consequently, they may be "forced to stay". However, because of the same resource constraints they may be "forced to move [out]" when their limited resources are exhausted (Kaczan & Orgill-Meyer, 2020, p. 288). These alternative propositions, however, have not been validated in a smallholder context.

The effects of the proposed institutional drivers may also vary. For example, access to credit is widely identified to positively affect the adoption new agricultural practices (Section 2.2). However, this relationship may not occur for the poor, since they may use the credit to meet other more pressing needs, or even in 'one-off luxury' (Jahiruddin et al., 2011). Similarly, although extension contact is widely found to affect the adoption of agricultural adaptation practices (Section 2.2); this may not happen with the poor because of a lack of relevance of the extension services to their contexts and needs (Glendenning et al., 2010; Sulaiman & Holt, 2002).

Wealth variations could moderate the Strategy → Outcome links as well. Adoption of a new high-yielding crop variety (an

SU indicator) may not increase poorer farmers' income (an Outcome indicator). Poorer farmers may not be able to afford and apply recommended amount of inputs (e.g., fertiliser, irrigation), resulting in lower yields and income. They often own less land and cultivate smaller plots (e.g., Lipton & Longhurst, 1985). This may increase their per unit cost of production due to a loss of economies of scale. Moreover, policies and market infrastructure may discriminate against the poor – a key characteristic of most developing countries. These factors were identified as the reasons why many Green Revolution (GR) technologies did not benefit the poor (e.g., Lipton & Longhurst, 1985; Pingali, 2012). Thus, instead of alleviating poverty, GR resulted in a transfer of poverty from rural to urban areas (Pingali, 2012). Similarly, when faced with a climatic disaster, both the poor and the rich may migrate to towns or urban centres. However, this strategy may have differential outcomes. The poor, due to their low skills, resources, and contacts, may end up having low-paid, manual, and less secure jobs, compared to the rich (Agarwal & Agrawal, 2017). This, in turn, could make the poor worse-off in terms of livelihood outcomes.

It is, however, unclear in the literature if these moderating effects of wealth are the same for the SO and SU strategies. Moreover, as mentioned, the literature is not based entirely on smallholders' contexts and there are debates regarding the exact direction of these effects. Thus, with regard to wealth, we hypothesise that the effects of the proposed six adaptation Drivers (Section 2.2) on both the SO and SU Strategies (Hypothesis 4) as well as the effects of both the SO and SU Strategies on Outcomes (Section 2.3) (Hypothesis 5) will significantly vary according to smallholders' farmland holding size.

3. Data and methods

3.1. Data source

The data for this study came from the coastal zone of Bangladesh – an area of 47, 211 km^2, covering 32% of the country's total area and 19 of the 64 districts (Abu et al., 2003). Around 36 million people (ca. 29% of Bangladeshi population) live in the coastal zone. The coastline includes mangroves, tidal flatlands, estuaries, grasslands, many small islands, accreted land, beaches, a peninsula, rural settlements, urban and industrial areas, and ports (Iftekhar, 2006; Hossain, 2001). Agriculture is the mainstay of the coastal livelihood (BBS, 2011). Shrimp and rice farming are predominant; however, farmers also cultivate vegetables and grow fruit trees in/around their homesteads, keep livestock (cattle, poultry, and duck), and rear fish (mainly native species) in ponds (Uddin & Nasrin, 2013).

The coastal zone in Bangladesh suffers from many climate-driven hazards, including salinity intrusion, temperature rise, decreasing rainfall, cyclones, tidal floods, and coastal/river erosion. Salinity-affected land in Bangladesh was 83.3 million hectares in 1973, which increased to 102 million hectares in 2000, and to 105.6 million hectares in 2009. Moreover, according to the data from Bangladesh Meteorological Department (BMD), the mean 'maximum' temperature in the nine study districts (Fig. 2) increased from 27.69 °C to 31.33 °C and the mean 'minimum' temperature increased from 22.6 °C to 23.07 °C between 2010 and 2016 (BMD, 2016). During the same period, the mean annual rainfall decreased from 66.8 cm in 2010 to 45.5 cm in 2016 (BMD, 2016). These changes contributed to increased salinity of farmlands, reduced agricultural productivity, increased pests and diseases, reduced biodiversity, shortage of pasturelands and fodder, disruption of drinking water supply, and health hazards (Aryal et al., 2020; Islam & Al Mamun, 2020; SRDI, 2010; Uddin & Nasrin, 2013). Furthermore, due to climate changes, coastal Bangladesh experiences tropical cyclones and tidal flooding regularly, with devastating effects on agriculture, households, economy, infrastructure, and human lives (BMD, 2020; Islam & Al Mamun, 2020). Notable examples include: cyclone Sidr in 2007, cyclone Aila in 2009, cyclone Mahasen in 2013, cyclone Roany in 2016, cyclone Mora in 2017, cyclones Fani and Bulbul in 2019, and cyclone Amphan in 2020. Cyclone Bulbul alone, for example, caused damages worth US$3.37 billion (BMD, 2020). Another problem facing this region is coastal (riverbank) erosion. Over a 20-year period from 1989 to 2009, an erosion from 20 m/year to 120 m/year was observed along much of the Bangladeshi coastal zone (Sarwar & Woodroffe, 2013).

Farmers in this region have been found adapting to these changes primarily by switching to shrimp and crab cultivation, diversifying crops, shifting to new fields, substituting crops with livestock, improving fertilizer management practices, selling households assets (including lands, livestock, jewellery, etc.), and outmigration (Akter & Ahmed, 2020; Aryal et al., 2020; The Daily Star, 2018).

For this study, nine out of the 19 costal districts were selected randomly (Fig. 2). From those, 11 Upazilas (sub-districts), 16 Unions, and 23 villages were selected successively (Table 1). Lists of the farm households of the selected villages were then obtained from the Sub-Assistant Agriculture Officers (SAAOs) concerned – employees of Bangladeshi government's Department of Agricultural Extension (DAE) working at the village level. From the total 6,695 households (study population), 803 households (12%) were randomly sampled (Table 1), which exceeded the minimal sample size required for the given population, with 5% Margin of Error, 99% Confidence Level, and 50% Response Distribution.[1] The heads (farmer and main decision maker) of the selected households were then interviewed face-to-face by a team of trained data enumerators, led by the co-authors of this paper. The local SAAOs helped introduce the data enumerators to the household heads. The data collection took place between May and December 2019 through several visits to the study sites by the research team.

For the survey, a structured questionnaire was used. Before designing the questionnaire, four focus groups were conducted in four villages of Satkhira and Bagerhat districts. In addition, key informant interviews were held with several Upazila Agriculture Officers (UAOs) and NGO fieldworkers in Shaymnagar Upazila of Satkhira district. These provided additional information regarding the trend of climatic changes in the study areas, their impacts on local livelihoods, and the adaptation strategies being adopted by farmers. Moreover, various publications and websites of the Government of Bangladesh departments, donor agencies, and NGOs were consulted. All these informed the design of the questionnaire which was then pilot-tested with 25 farmers, and accordingly, revised and finalised.

Before conducting the study, formal ethical approvals were obtained from the authors' affiliated universities. Informed consents were also obtained from the selected households and other interviewees. Anonymity and confidentiality of the participants have been strictly maintained throughout the study.

3.2. Variables, measurement, and analysis

Ten indicator variables, including agricultural and non-agricultural activities, resembling those in the literature (Section 2.1) and relevant to the study areas (Section 3.1), were used to measure smallholders' climate change adaptation Strategies (Fig. 4A). The interviewees were asked to indicate their adaptation practices over 12 years, from 2007 to 2019. This timeline was cho-

[1] This can be calculated from http://www.raosoft.com/samplesize.html.

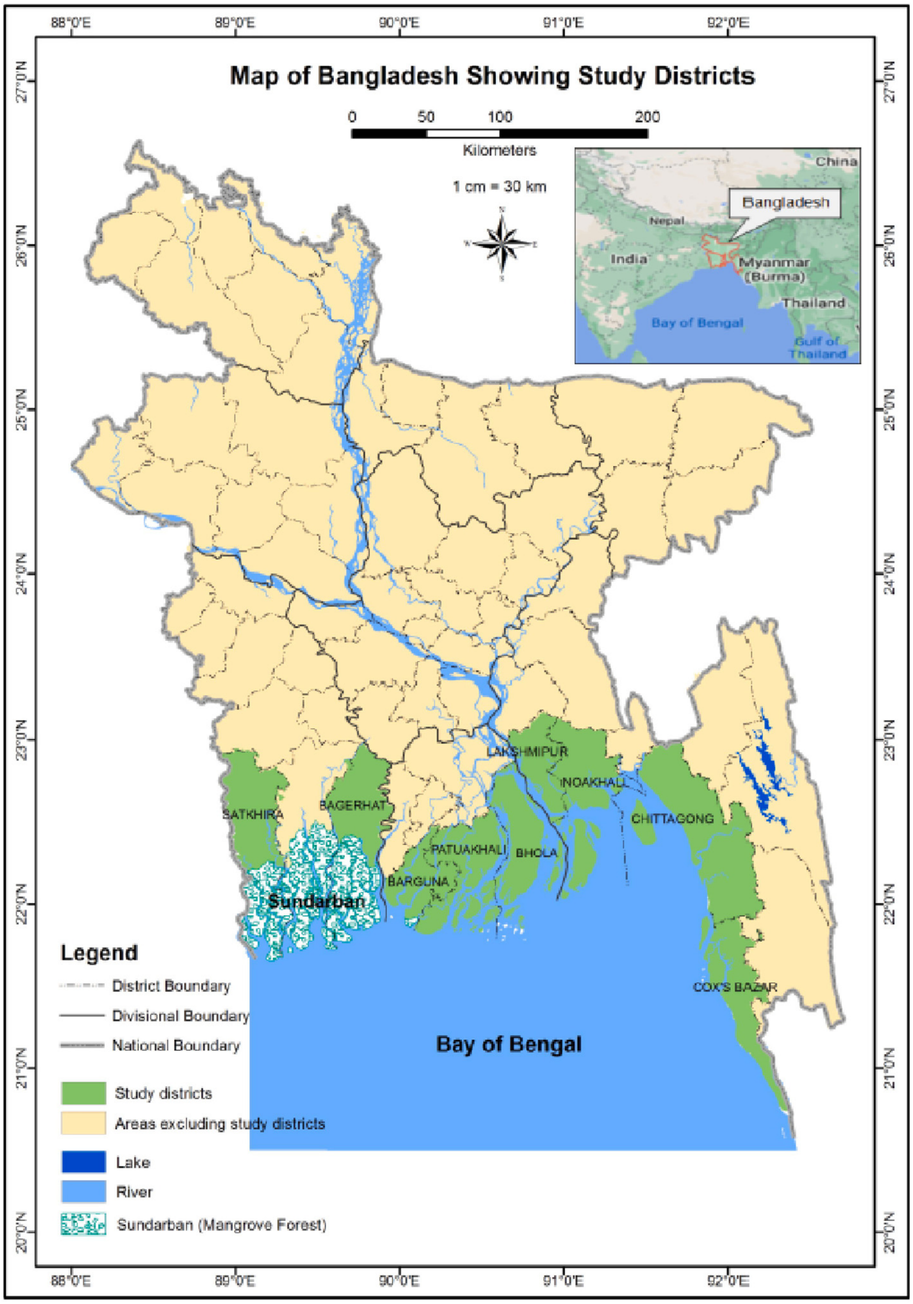

Fig. 2. Locations of the coastal districts in Bangladesh where data for this research were collected (map credit: Neelima Akter Kohinoor, PSO, SRDI, Bangladesh).

sen because of the ravaging 2007 cyclone Sidr, which was vivid in the memory of the interviewees, and thus helped them to recall their adaptation practices easily. The measurement scales were adjusted according to the intervals to which the households said (during the initial focus groups) that they had adopted those measures. For instance, permanent migration of household member(s) does not happen every year and therefore a binary "yes/no" scale was used, while cultivation of resistant varieties could be a yearly phenomenon and therefore the scale "always" (almost every year), "sometime" (once in every 2–3 years), "rarely" (once in >3 years) and "never" was used.

Of the six adaptation Drivers considered in this study, perception was measured on a 7-point Likert-type scale, ranging from "highly decreased" (1) to "highly increased" (7), about temperature and the intensities and frequencies of rainfall, tidal surge, salinity, storm/cyclone, flood, drought, and coastal/riverbank erosion (Fig. 4B). Exposure-damages was measured on a 4-point Likert scale (never, rarely, sometime, and always) covering 12 damage items relating to soil, crop, livestock, poultry, and household members (Fig. 4C). Extension contacts included the frequency of contacts of the household heads with various government and non-government organisations as well as their participation in various extension events – all measured on Likert-type scales (Fig. 4D). The rest three variables were measured on continuous scales: distance from nearest coast/river in kilometre, amount of credit received within the last 12 years in Bangladeshi Taka (later converted to US$), and membership experience in local groups/associations in years. Five sources of credit – including NGO microcredit, village samitees (non-NGO), banks, village moneylenders, and friends/relatives – were considered. Membership included seven local organ-

Table 1
Distribution of the population and sample of this study.

District	Upazilla	Union	Village	Total no. of households	No. of households selected
Satkhira	Shyamnagar	Munshigonj	Munshigonj	415	50
		Burigoaliny	Chandipur	322	40
Bagerhat	Mongla	Chila	Haldibunia	388	45
		Chadpai	Chadpai	372	45
Borguna	Amtali	Gulishakhali	Maheskhali	384	45
		Haladia	Chunakha	378	45
Patuakhali	Dumki	Angaria	Angaria	463	55
		Sreerampur	Sreerampur	375	45
Bhola	Charfasson	Jahanpur	Jahanpur	250	30
		Rosulpur	Vashanchar	211	25
		Aslampur	Ayeshabad	225	25
		Aslampur	Aligao	165	20
Noakhali	Hatiya	Horni	Jotkhali	207	25
			Rasulpur	175	20
			Ahmadpur	168	20
			Govindapur	205	25
Laxmipur	Ramgati	Char Alexander	Char Daktar	292	35
			Sujongram	255	30
			Char Mayer	271	35
Chittagong	Banskhali	Chanua	Chanua	335	40
			Kutubkhali	288	35
Cox's Bazar	Pekua	Toitong	Dhaniaghata	276	35
	Chakaria	Dhemoshia	Ilishia	275	33
Total				**6,695 (100%)**	**803 (12%)**

isations – Farmer Field School (FFS) groups, NGO groups, professional groups/cooperatives, village saving-credit groups (non-NGO), religious groups, sports/youth groups, and school/madrasa committees.

Ten indicator variables, resembling those in the relevant literature (Section 2.3), were used in measuring the adaptation Outcome variable (Table 4). Respondents were asked to indicate changes on those indicators compared to the pre-Sidr era. A simple scale of "has improved, has remained the same, and has declined" was used. The indicators and scale were selected based on the initial focus groups, which allowed an observation of how the smallholders themselves evaluated and described their aspirations and well-being in everyday languages. By doing so, we empowered the smallholders and considered what they thought was important for them (Scoones, 1998). The proxy indicator for wealth – ownership of agricultural lands – was measured in local units and later converted to acres.

Following data cleaning and exploratory analyses, composite scores for the adaptation Drivers, Strategies, and Outcomes were created. Since the scale of the Strategy variable was categorical and mixed (e.g., binary and ordinal), the Categorical Principal Component Analysis (CATPCA) procedure in SPSS version 25 was used (IBM, undated). For three of the Driver variables with ordinal-categorical scales (Fig. 4B-4D), the Likert's method of summated ratings was used. Before creating the summated scores, the reliability (Cronbach's alpha) of the scales were checked. Three Driver variables – distance, credit access, organisational membership – did not require any aggregation as they were measured on continuous scales. For the Outcome variable, a widely used PCA-based aggregation technique pioneered by Filmer and Pritchett (2001) was used. At first, all the outcome indicators were dummy-coded into "improved (1)" and "not-improved (0)", and then, were subjected to a PCA, which provided a one-component solution.

To test our proposed hypotheses, we used Structural Equation Modelling (SEM) in IBM SPSS Amos version 25 (Arbuckle, 2017). A SEM is a method of simultaneous regression, in which one independent variable in one equation is used as a dependent variable in another equation. The SEM also allows one to simultaneously identify the correlational paths between variables. SEM can be used with both observed and/or unobserved (latent) variables (Bollen, 1989). However, in our analysis, we considered all our variables as observed (Bollen, 1989). A SEM model with observed variables can be written as (Bollen 1989):

$$y = B_y + \Gamma_x + \zeta$$

where,

B = m $\times$ n coefficient matrix
Γ = m $\times$ n coefficient matrix
y = p $\times$ 1 vector of endogenous variables
x = q $\times$ 1 vector of exogenous variables
ζ = p $\times$ 1 vector of errors in the equations

The Maximum Likelihood (ML) method was used in model estimation. Although the ML algorithm is generally robust against non-normal data, we still checked the distribution of all the variables, by observing the histograms and measures of skewness and kurtosis. A skewness of $\leq$2.0 and kurtosis of $\leq$7.0 was considered acceptable (Kim, 2013).

We used the regression weights and their significance to test Hypotheses 1 and 2. To test the 'mediatory' effect of the Strategy variables (Hypothesis 3), we examined the conditions shown in Fig. 3. For this, we added direct paths from the Driver variables

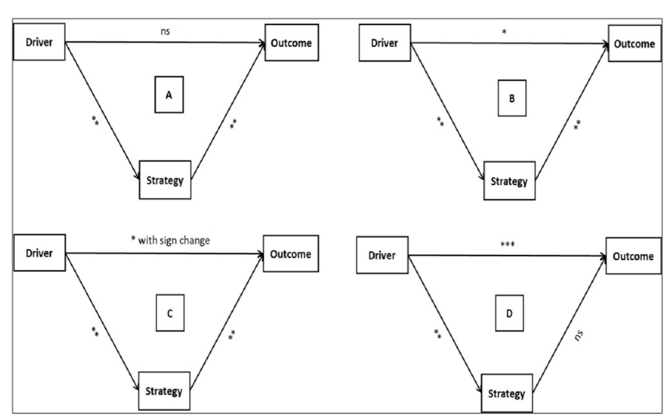

Fig. 3. Mediation tests for the Strategy variables (adapted from Little et al., 2007): (A) full mediation; (B) partial mediation; (C) inconsistent mediation; (D) no mediation; ns = not significant; */**/*** = relative strengths of the effects, with *** being the strongest).

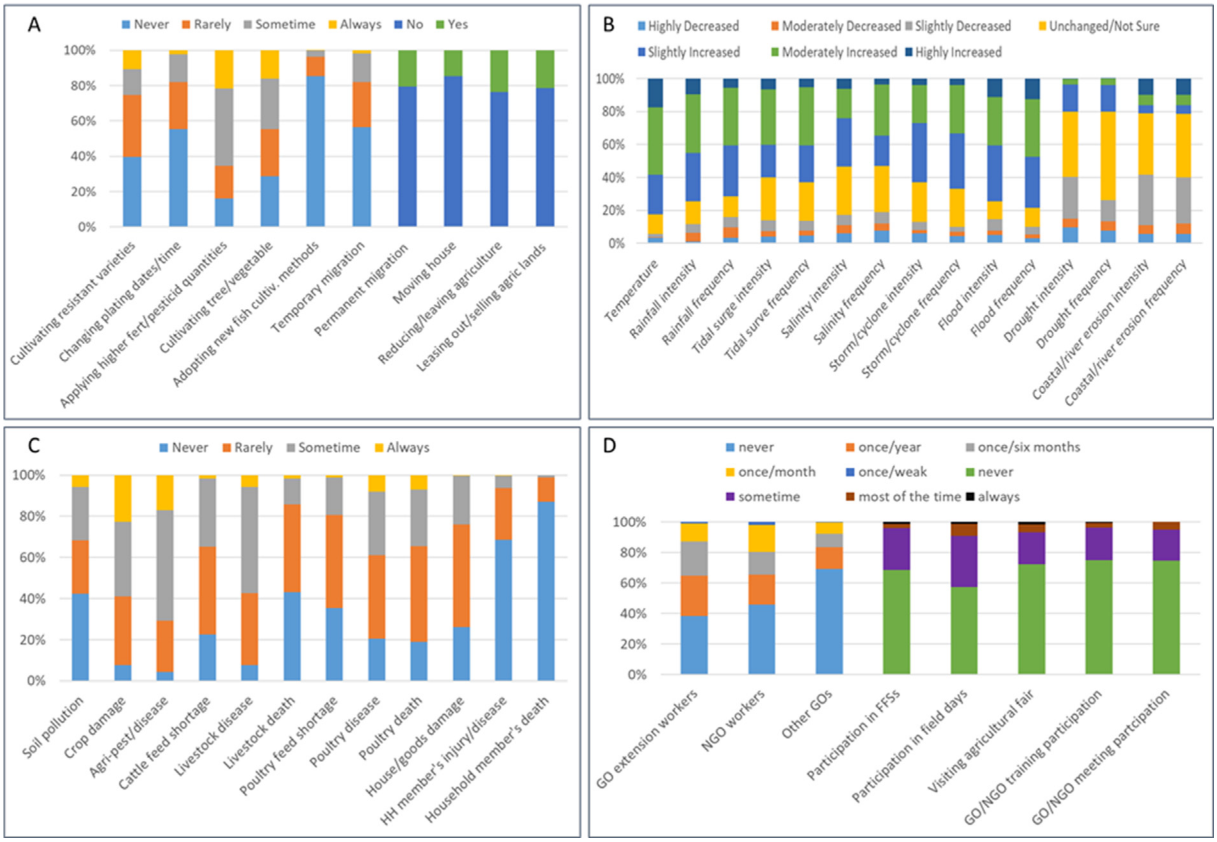

Fig. 4. (A) Adaptation practices adopted by the smallholders; (B) Smallholders' perception of climatic changes (variabilities and extremes); (C) Exposure and damages to smallholder households related to climatic changes; (D) Extension contacts of the smallholders.

to the Outcome variable (Appendices A1-A3). This analysis helped us to identify the extent to which the observed effects on the Outcome variable was actually due to the Strategy variables.

To test if the causal links between the Drivers, Strategies, and Outcomes significantly varied according to landholding size (Hypotheses 4 and 5), we conducted a 'moderation' test (Little et al., 2007) by using the multi-group comparison analysis in Amos (Arbuckle, 2017). For this, we created a categorical variable: small landholder (≤2.49 acres), medium landholder (2.5 to 7.49 acres) and large landholder (≥7.5 acres), based on the farm classification criteria in Bangladesh (BBS, 2010). Critical ratios (C.R.) for differences between the regression weights of these landholder groups were then examined. C.R. values exceeding ±1.96 were considered as significant and used as evidence of moderation. To confirm if our models were plausible, we used several commonly-used fit indices, as shown in Table 2.

4. Results

At first, we present the results of our descriptive analyses in Sections 4.1–4.4 and then the results of our Structural Equation Modelling in Section 4.5.

4.1. Adaptation strategies

Descriptive analyses of the 10 Strategy items (Fig. 4A) indicated that the application of higher quantities of fertilisers/pesticides was the most prevalent adaptation measure adopted by over 80% smallholders. The next in prevalence (ca. 70%) was the cultivation of tress/vegetables. Over 60% smallholders adopted resistant varieties, but only around 10% every year ("always" on the scale). In over one-fifth households, member(s) migrated permanently to other areas. Temporary/seasonal migration, however, was more prevalent (>40%). Over one-fifth of the smallholders had sold or leased-out whole or a part of their agricultural lands, e.g., to commercial shrimp farm (gher) owners.

Categorical Principal Component Analysis of the 10 adaptation items produced two distinct components (Table 3). Of the Component 1 items, leasing or selling agricultural lands, and of the Component 2 items, cultivation of resistant varieties had the highest loadings. Having considered the loading patterns, Component 1 was defined as a Stepping Out strategy, whilst Component 2 as a Stepping Up strategy. The total variance explained by the components and the scale reliability were acceptable.

Table 2
Fit indices used in evaluating the SEM models in this research (Source: Hooper et al., 2008; Schermelleh-Engel & Moosbrugger, 2003).

	ChiSq/d.f.	NFI	CFI	IFI	RMSEA
Good Fit	0 ≤ ChiSq ≤ 2	0.95 ≤ NFI ≤ 1.0	0.97 ≤ CFI ≤ 1.0	Not known	0 < RMSEA ≤ 0.05
Acceptable Fit	2 < ChiSq ≤ 3	0.90 ≤ NFI < 0.95	0.90 ≤ NFI < 0.97	>0.95	0.05 < RMSEA ≤ 0.08

Table 3
Component loadings of the Strategy variables.

Adaptation practices	Loadings	
	Component 1	Component 2
Cultivation of stress-resistant crop varieties	−0.138	**0.760**
Changing the date/time of crop planting	−0.132	**0.746**
Using higher dosage/quantities of fertilisers/ pesticides	0.512	**0.699**
Cultivating trees/vegetables in and/or around the homestead	−0.100	**0.689**
Adoption of new fish cultivation methods – cultivation of shrimp during high salinity and fish during low salinity	−0.008	**0.492**
Moving house to safer areas	**0.464**	0.016
Household head has reduced/left agriculture to start a new job/business	**0.740**	0.054
Temporary migration of one/more household members to other areas or towns	**0.746**	−0.024
Permanent migration of one/more household members to other areas/towns	**0.791**	−0.145
Leasing out or selling agricultural lands	**0.828**	−0.112

Method: Variable Principal Normalization. Rotation: Promax with Kiser Normalisation.
Cronbach's Alpha 0.903; total variance explained 53.5% (Comp 1 = 32.99%; Comp 2 = 20.52%).

4.2. Adaptation drivers

Over 70–80% of the farmers (household heads) perceived that, during 2007–2019, temperature, rainfall, and floods had increased both in frequency and intensity (Fig. 4B). For salinity, the distribution was around 50%. Drought was the least concern (dropped from further analysis). The composite scores ranged from 30 to 100, with a mean of 68.96 and standard deviation of 11.05. Nearly 50% of the farmers had scores ca. 70, whilst 75% up to 77. The skewness (−0.83) and kurtosis (1.42) estimates were within acceptable range. The scale had an acceptable reliability score of Alpha 0.819.

Crop-related damages and pests/diseases were the most prevalent, whereas casualties to household members the least prevalent (Fig. 4C). The observed summated scores ranged from 11 to 35, with a mean of 22.81 and standard deviation of 4.04. Around 25% households had scores up to 20 and 75% up to 25. The skewness (−0.15) and kurtosis (0.39) estimates as well as the reliability (Alpha 0.665) of the scale were acceptable.

The distance of the households from the nearest coasts/rivers ranged from 0.10 Km to 15.0 Km, with a mean of 2.37 Km and standard deviation of 2.19 Km. Around 50% were within 1.5 Km and 75% within 3 Km. One household, located 35 km away, was dropped from further analysis as an outlier. The kurtosis (6.23) was acceptable; however, the skewness (2.07) was slightly higher.

Within the last 12 years, around 57% of the households did not receive any credit at all. The highest amount was ca. US$6,471; mean $221; and standard deviation $497. Up to 75% received $176. One household with an unusually high amount of US $23,530 (outlier) was dropped from further analysis. The skewness and kurtosis estimates (5.37 and 47.26, respectively) indicated significant departure from normal distribution; therefore, before modelling, the variable was transformed to a normal distribution by using the Inverse Distribution Function procedure in SPSS (although the difference in SEM estimates between the transformed and non-transformed variables was found negligible).

Around 55% of the farmers had no organisational affiliation at all. The maximum was 24 years, mean about 2.5 years, and standard deviation 3.77 years. Up to 75% of them had only 4 years of experience. The skewness and kurtosis estimates (1.97 and 4.92, respectively) were acceptable.

Extension contacts of the farmers were mostly with the field-workers from the Department of Agricultural Extension of the government of Bangladesh and from NGOs (Fig. 4D). Slightly over one-third had contacts with other government organisations. Slightly over 40% of the farmers participated in extension field days and around 30% in other extension activities. The summated scores ranged from 0 to 22 (mean 4.6; standard deviation 4.21), with ~25% having scores up to 1, 55% up to 4, and 75% up to 7. The skewness (0.92), kurtosis (0.59), and reliability (Alpha = 0.794) estimates were within the acceptable range.

4.3. Adaptation outcomes

Descriptive analyses of the 12 Outcome indicators revealed an encouraging picture, with a vast majority of the households reporting improvements in their circumstances compared to the situation 12 years ago (i.e. the pre-Sidr era; see Section 3.2). Yet ~20–30% of the households reported no improvement in their circumstances (Table 4).

The index (component) scores ranged from −3.27 to 1.39, with ~ 35% households falling below the mean (0), ~ 50% up to 0.5, and ~75% up to 0.6. The index had sound KMO & Bartlett's statistics and the first principal component (PC1) explained an acceptable proportion of the total variance in the data (Table 4). The skewness (−1.23) and kurtosis (0.67) estimates were acceptable. Food and health indicators had higher loadings on the index variable.

4.4. Adaptation drivers, strategies, and outcomes according to landholding size

Farmland ownership in the sample ranged from 0.05 to 12.8 acres (mean 1.8 acres; standard deviation 1.38 acres). Up to 25% had 0.73 acre, 50% had 1.4 acres, and 75% had 2.6 acres. After categorising the farmland ownership according to the farm size classifications of Bangladesh, 586 households (73%) fell within the "small" landholder category (≤2.49 acres), 215 households within the "medium" landholder category (2.5–7.49 acres), and only two households within the "large" landholder category (≥7.50 acres) (excluded from further analysis).

Table 4
Descriptive statistics of the indicator variables used in creating the Outcome index variable.

Outcome indicators	Mean	Std. Deviation	PC1 Loadings*
Household's agricultural production has improved (0,1)	0.806	0.396	**0.460**
Household's income has improved (0,1)	0.826	0.380	**0.624**
Consumption of adequate and nutritious foods by all household members has improved (0,1)	0.772	0.420	**0.782**
Clothing for all household members has improved (0,1)	0.747	0.435	**0.752**
Education for household children has improved (0,1)	0.863	0.344	**0.494**
Medical treatment/care for household members has improved (0,1)	0.766	0.424	**0.793**
Sanitation facilities for household members has improved (0,1)	0.750	0.433	**0.536**
Health status of household adults has improved (0,1)	0.665	0.472	**0.601**
Health status of household children has improved (0,1)	0.790	0.408	**0.719**
Housing facilities for household members has improved (0,1)	0.762	0.426	**0.538**

*Kaiser-Meyer-Olkin measure of Sampling Adequacy 0.856; Bartlett's test of Sphericity $p < 0.001$; Total Variance explained by the first principal component (PC1) = 41.058%.

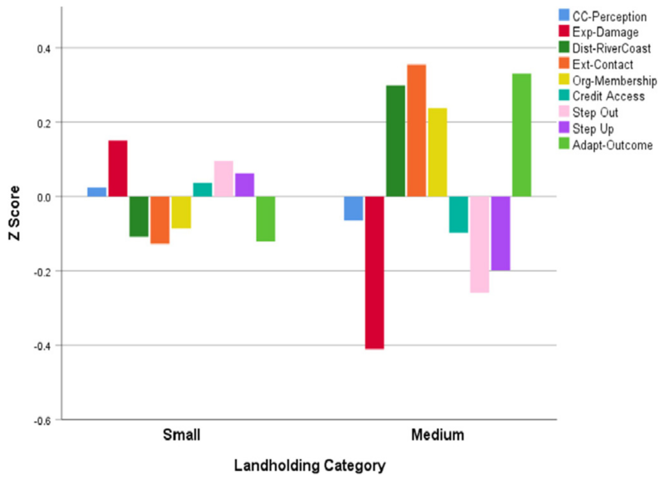

Fig. 5. Adaptation Drivers, Strategies, and Outcomes according to farmland holding categories.

The standardised scores of all the variables are compared according to landholding size in Fig. 5. Huge contrasts can be seen. The small landholders had higher scores for climate change perception and exposure-damages. They were located closer to coasts/rivers, had lower organisational experience, lower extension contacts, and lower Outcome scores. However, small landholders had higher scores for credit access and for the Strategy variables.

4.5. Adaptation drivers, strategies, and outcomes – connecting the dots

The path diagrams obtained from Structural Equation Modelling (SEM) are shown in Appendix A (Figs. A1, A2 and A3). The models had 'acceptable' to 'good' fit according to commonly used indices (Table 5) and explained between 17–38% variance in Step-Out, 16–35% in Step-Up, and 27–35% in Outcome.

While the CATPCA procedure indicated two alternative Strategies (Section 4.1), the SEM models confirmed it further. As can be seen in Fig. A1, the correlation between SO and SU is significant ($p < 0.001$) and negative, confirming that the pathways were bipolar, i.e. an increase in one strategy would result in a corresponding decrease in the other. The Drivers and Outcomes of these alternative Strategies are presented in Sections 4.5.1 and 4.5.2, respectively.

4.5.1. Effects of adaptation drivers on strategies

Overall, five of the six Driver variables revealed statistically significant effects on both the Step-Out (SO) and Step-Up (SU) strategies (Table 6). One variable, extension contact, had a non-significant effect on SU, but had a significant effect on SO. Therefore, we consider Hypothesis 1 (Section 2.2) to be correct.

The direction and magnitude of the effects are however not the same. The overall model indicates that the higher the perception of climatic variability and extremes, exposure-damage, and extension contacts, the more likely the smallholders will be to SO. Moreover, the higher the distance from rivers/coasts, organisational membership experience, and credit access, the less likely they will be to do so. Overall, the largest driving effect on SO was of perception (Beta 0.204; $p < 0.001$), followed by extension contact (Beta 0.194; $p < 0.001$), and asset damage (Beta 0.170; $p < 0.001$). The largest deterring effect was of distance (Beta −0.184; $p < 0.001$), followed by org-membership (Beta −0.117; $p < 0.001$) and credit access (Beta −0.086; $p < 0.01$).

The SU strategy was likely to be driven by exposure-damage, organisational membership, and credit access; whilst deterred by perception, and distance. The largest driving effect was by credit access (Beta 0.231; $p < 0.001$) and the largest deterring effect by climate change perception (Beta −0.219; $p < 0.001$).

A comparison between SO and SU revealed that two variables – exposure-damage, and proximity (opposite to 'distance') – could drive both Strategies; each of the three variables – perception, organisational membership, and credit access – affected the Strategies in opposite directions, i.e. acted as a driver for one strategy, whilst as a deterrent for the other; and one variable, extension contact, affected SO only.

We also found significant correlations between the 'natural' and 'social' drivers (Figs. A1, A2 and A3). For example,

Table 5
Fit indices and explained variance of the path models.

Models	Fit indices					Variance explained		
	ChiSq/DF	NFI	IFI	CFI	RMSEA	Step-Out	Step-Up	Outcome
Overall	2.533	0.954	0.971	0.969	0.031	17.1%	17.8%	28.5%
Small Landholder	n/a*	n/a	n/a	n/a	n/a	16.5%	16.1%	26.6%
Medium Landholder	n/a	n/a	n/a	n/a	n/a	37.7%	35.4%	34.8%

*In multi-group comparative analyses, as in this research, Amos provides fit indices for the main model only.

Table 6
Effects of the Driver variables on the Strategy variables.

Regression paths	Reg. Coeff. Overall Model	Reg. Coeff. Small Landholder Model	Reg. Coeff. Med. Landholder Model	C.R[a]. (Small versus Medium Landholders)
CC-Percept≫Step-Out	0.204***	0.234***	0.054^n.s.	−2.076 (sig.)
CC-Percept≫Step-Up	−0.219***	−0.26***	0.089^n.s.	3.822 (sig.)
Exp-Damage≫Step-Out	0.170***	0.091*	0.298***	2.532 (sig.)
Exp-Damage≫Step-Up	0.168***	0.145***	0.108^n.s.	−0.426 (n.s.)
Dist-RivCoast≫Step-Out	−0.184***	−0.248***	−0.01^n.s.	3.812 (sig.)
Dist-RivCoast≫Step-Up	−0.148***	−0.075^n.s.	−0.217***	−2.208 (sig.)
Ext-Contact≫Step-Out	0.194***	0.103**	0.532***	5.845 (sig.)
Ext-Contact≫Step-Up	0.059^n.s.	0.079*	0.132*	0.694 (n.s.)
Org-Memb≫Step-Out	−0.117***	−0.086*	−0.222***	−2.087 (sig.)
Org-Memb≫Step-Up	0.094**	0.058^n.s.	0.173**	1.707 (n.s.)
Credit≫Step-Out	−0.086**	−0.086*	−0.038^n.s.	0.578 (n.s.)
Credit≫Step-Up	0.231***	0.157***	0.636***	5.508 (sig.)

*Significant at 5% level; **Sig at 1% level; ***Sig at 0.1% level; n.s. denotes not significant. All regression coefficients are standardised values. [a] Critical Ratios for differences between regression weights (beyond ± 1.96 is significant).

exposure-damage, a natural variable, was positively correlated with extension contacts, and credit access.

Moderation tests revealed significant variations between the small and medium landholders (Table 6). Perception had significant effects on both the Strategies of small landholders, whilst it had non-significant effects on medium landholders. These variations were statistically significant. Exposure-damage had a significantly larger and positive effect on the SO of medium landholders, compared to the small landholders. Distance had a significantly larger and negative effect on the SO of small landholders; whilst it had a significantly larger and negative effect on the SU of medium landholders. The effects of extension contact, and organisational membership were significantly larger on the SO of medium landholders. A significantly larger effect of credit access on the SU of the medium landholders was also found. In consideration of these, we consider Hypothesis 4 (Section 2.4) to be acceptable.

Some interesting contrasts were found in the correlational paths of the small and medium landholder models. Distance was significantly correlated with exposure-damage in the small landholder model (Fig. A2), but not in the medium landholder model (Fig. A3). Exposure-damage had a non-significant correlation with credit access in the small landholder model, whist it had a significant and positive correlation with credit access in the medium landholder model.

4.5.2. Effects of adaptation strategies on adaption outcomes

SO had a large and negative effect (Beta −0.425; $p < 0.001$) on Outcome. SU in contrast, had a modest but positive effect (Table 7). Therefore, Hypothesis 2 (Section 2.3) proved to be correct.

A similar pattern of effects as in the overall model can be seen in the small and medium landholder models, except that the effect of SU on the medium landholders was non-significant. The variations in these effect sizes between the small and medium landholders were not statistically significant, resulting in us to reject Hypothesis 5 (Section 2.4).

Regarding the 'mediatory' role of the Strategy variables (see Fig. 3 for associated methods), it can be seen (Table 7 and Fig. A1) that, in the overall model, the direct effects of the Driver variables on the Outcome variable are either non-significant or lower compared to the direct effects of the Strategy variables on the Outcome variable. Moreover, all the Drivers had significant effects on the Strategy variables (Table 6 and Fig. A1). This confirmed that the Strategy variables played significant mediatory roles between the Driver and the Outcome variables, leading us to accept Hypothesis 3 (Section 2.3).

5. Discussion and conclusions

In this research we aimed to investigate which adaptation strategies – agricultural versus non-agricultural – provides better developmental outcomes for smallholders; if the drivers of these strategies are different; and whether these driver and outcome effects vary according to farmland holding size. For this, we used the Stepping Out (SO) and Stepping Up (SU) typology of Dorward et al. (2009) and a holistic framework based on the climate change and livelihoods literature.

The SO-SU typology proved useful to achieve the study's aims. The use of multiple indicators, along with an aggregation technique based on Principal Component Analysis (PCA), was theoretically and empirically more meaningful than the predominant trend in the existing literature of focusing on individual practices. Our findings reinforce others' observation that a smallholder does not adopt a single practice in isolation (Khanal & Wilson, 2019) and therefore relating such individual practices with complex livelihood outcomes – such as poverty alleviation or food security (Bailey et al., 2019; Rahut & Ali, 2017) – can be sketchy. Additionally and uniquely, our study illustrates the limitations of aggregating agricultural and non-agricultural practices together (e.g., as in Khanal & Wilson, 2019; Tesfahun & Chawla, 2020) by revealing that these strategies can be mutually-exclusive.

Unlike the existing literature, the application of the SO-SU typology, along with novel methods, i.e. Structural Equation Modelling (SEM) with 'mediation' tests, helped us confirm with confidence that 'adaptation strategies do matter' in reducing smallholders' vulnerabilities and improving their household wellbeing. Further unique insights are noteworthy. Contrary to widespread speculations (e.g., DFID, 2015; Global Donor Platform for Rural Development, 2019; Hansen et al., 2019; Stringer et al., 2020) we found that the SO strategy, which included reducing or exiting agriculture (Table 3), had a large negative effect on smallholders' livelihood outcomes, irrespective of their farm sizes. This seems to substantiate the arguments against farm-exit (Agarwal & Agrawal, 2017; Kerssen, 2015; La Via Campesina, 2009; Li, 2009; Taylor, 2015). Although, we did not investigate why SO had a negative effect, several probable reasons are mentioned in the literature, including an uncertain or underdeveloped informal labour market, and low skills and education among smallholders (Agarwal & Agrawal, 2017; Taylor, 2015).

Our finding regarding the positive effect of the SU strategy also contradicts with others (DFID, 2015; Global Donor Platform for Rural Development, 2019; Stringer et al., 2020) by revealing that smallholders can successfully improve and benefit from agriculture. Through 'moderation' analyses, we generate more nuanced and unique insights. Contrary to unverified suggestions, such as <2 ha being a barrier to SU (Stringer et al., 2020), we reveal that even the 'smallest of smallholders', owning agricultural lands of <2.5 acres (~1 ha) only, could better their livelihood outcomes by adopting SU. Our study also shows that, when faced with climatic changes, they are more likely to adopt SU than the larger landholders (Fig. 5). A reason for such contrast could be that arguments against the developmental impacts of smallholder agriculture are

Table 7
Effects of the Strategy and the Driver variables on the Outcome variable.

Regression paths	Reg. Coeff. Overall Model	Reg. Coeff. Small Landholder	Reg. Coeff. Medium Landholder	C.R.[a] (Small versus Medium Landholders)
Step-Out≫Outcome	−0.425***	−0.39***	−0.387***	0.034 (n.s.)
Step-Up≫Outcome	0.139***	0.156***	0.083$^{n.s.}$	−1.166 (n.s.)
CC-Percept≫Outcome	−0.074*	−0.083*	0.005$^{n.s.}$	1.334 (n.s.)
Exp-Damage≫Outcome	−0.052$^{n.s.}$	−0.048$^{n.s.}$	0.069$^{n.s.}$	1.798 (n.s.)
Dist-RivCoast≫Outcome	0.111***	0.179***	−0.045$^{n.s.}$	−4.073 (sig.)
Ext-Contact≫Outcome	0.111***	0.104*	0.008$^{n.s.}$	−1.493 (n.s.)
Org-Memb≫Outcome	0.031$^{n.s.}$	0.02$^{n.s.}$	0.038$^{n.s.}$	0.33 (n.s.)
Credit≫Outcome	0.015$^{n.s.}$	0.007$^{n.s.}$	0.061$^{n.s.}$	0.789 (n.s.)

*Significant at 5% level; **Sig at 1% level; ***Sig at 0.1% level; n.s. denotes not significant. All regression coefficients are standardised values. [a] Critical Ratios for differences between regression weights (beyond ± 1.96 is significant).

predominantly based on the narrow economic indicators of efficiency, productivity, profitability, and competitiveness (e.g., DFID, 2015), whilst we assessed the effects of the SU strategy on a broader set of livelihood outcomes (Section 4.3). Moreover, in our research, SU included a diversity of innovations – not only the cultivation of resistant varieties, but also homestead vegetable/tree cultivation, and new fish cultivation methods. Recent research (Biru et al., 2020) finds that the adoption of such 'multiple complementary technologies' could reduce smallholders' poverty and vulnerability.

By analysing six climatic-geographic and institutional factors, we generate important new insights regarding the drivers of SU versus SO. Contrary to other studies (Islam et al., 2020; Khan et al., 2020; Luu et al., 2019; Sadiq et al., 2019; Samuel & Sylvia, 2019) we found climate change perceptions to deter SU, and trigger SO. Moderation analyses helped clarify this finding, by indicating that these effects were significant for small landholders only. Whilst, in line with other studies we confirmed that proximity to rivers/coasts (opposite to 'distance') and exposure-damage could trigger SO (Kaczan & Orgill-Meyer, 2020; Shameem et al., 2014; The Daily Star, 2018; Tittonell, 2014), we revealed that these factors could drive SU as well. Moderation analyses further indicated that proximity was a driver of SO for small landholders only. Noticeably, consistent with the suggestion in the literature (Barbier, 2015; Islam & Winkel, 2017; Neumann et al., 2015), we found the small landholders (by extrapolation, poorer) living closer to coasts/rivers (Fig. 5), i.e., in a more risk-prone environment. This had resulted in their higher exposure-damage (see Fig. 5 and the inverse correlation between 'distance' and 'exposure-damage' in Fig. A2). Such damages to their already scarce resources meant that they were "forced to move [out]" (Kaczan & Orgill-Meyer, 2020, p. 288), in which their extension contacts played a role (Fig. A2). Proximity, however, drove the larger landholders to SU, rather than to SO. This action was uncorrelated with their exposure-damages but correlated with credit access. Exposure-damages could drive medium landholders to SO as well; however, this effect was not due to their proximity to coasts/rivers and was correlated with extension contacts (Fig. A3).

Regarding institutional drivers, we confirm the positive effects of organisational membership and credit access on SU, as observed in numerous studies (e.g., Arunrat et al., 2017; Nganga et al., 2016; Rahut & Ali, 2017; Sadiq et al., 2019; Samuel & Sylvia, 2019; Tesfahun & Chawla, 2020; Khan et al., 2020). Uniquely, however, we find that these factors not only drove SU, but also deterred SO. Moderation analyses also generated new insights regarding the variations between small and medium landholders. For instance, the driving effect of organisational membership on SU was significant for medium landholders only. The driving effect of credit access on SU was significant for both groups, but the effect size was significantly larger for medium landholders. The deterring effect of organisational membership on SO was significantly larger for larger landholders, whereas the deterring effect of credit on SO was significant for small landholders only. Moreover, contrary to the literature (e.g., Arunrat et al., 2017; Nganga et al., 2016; Rahut & Ali, 2017; Sadiq et al., 2019; Samuel & Sylvia, 2019; Tesfahun & Chawla, 2020; Khan et al., 2020), we found a non-significant effect of extension contact on SU, with the effects not being different between small and medium landholders. Rather unexpectedly, we found a positive effect of extension contact on SO, with the effect size being significantly larger for larger landholders. The non-significant effect of extension contact on SU may be due to low quality of the services provided (Mamun-ur-Rashid et al., 2018), or their lack of relevance to the needs and contexts of the farmers (Glendenning et al., 2010; Sulaiman & Holt, 2002). The positive effect on SO may relate to Bangladeshi government's promotion of rural non-farm employments, as espoused in the 2016–2020 five-year plan (GED, 2015). Consequently, extension workers may have provided information, not only on agriculture, but also on non- or off-farm job opportunities, which influenced the SO, especially of the larger landholders.

We recognise that our study's findings may be more relevant to low-lying deltaic regions (e.g., the Indo-Gangetic plain) and that other contexts may require other drivers to be investigated. Yet, some general conclusions can be drawn from this study. Firstly, both natural and social (institutional) factors, and their interactions, drive smallholders' adaptation, in which institutions play a mediatory role. Secondly, whereas natural-environmental factors like proximity and exposure-damages could drive both SO and SU; psychological-institutional factors may have contrasting effects, with the same factor acting as a driver for one strategy, whilst as a deterrent for the other. Thirdly, the drivers of adaptation may vary significantly according to farmland holding size (by extrapolation, wealth). The first conclusion is well-established in the Sustainable Livelihoods literature (Scoones, 1998; Serrat, 2017); however, the rest two are unique and may enrich from further evidence.

From a practice perspective, these findings have important implications. The negative outcomes of the SO strategy mean that development practitioners and donors should carefully consider this pathway. It is discernible that the advocates of 'stepping out' (farm-exit in a narrow sense) base their arguments on the historical trajectories of agrarian transformation in the West and other successful market economies (e.g., Japan, South Korea, Taiwan). Our study suggests that this premise may not be relevant in a climate change context, where the driver of step-out is 'climatic push' (helplessness and vulnerabilities), rather than 'market pull' (e.g., growth in manufacturing and service sectors). In such circumstances, we need to be profoundly cautious in pursuing the idea that informal labour markets would provide more secure livelihoods for those ejected from farming (Taylor, 2015). In this regard, decisions should be evidence-based (rather than top-down), investigating what actually is driving step-out in a country or region, and what 'better' alternative livelihoods are available for those stepping out of farming. Moreover, to manage a successful transition for such farmers, it would be essential to adopt appropriate mitigating measures, e.g., devising effective labour market policies, investing in infrastructure, programmes on non-formal education and skills development, and employment-support schemes (Agarwal & Agrawal, 2017; FAO 2017). We should remind ourselves that many slum dwellers in the urban areas of developing countries tend to be those ejected from or left farming; however, there is no evidence that they have reduced their vulnerabilities to climatic changes and have achieved better livelihood outcomes. Rather, increased crowding of cities has been found to increase poverty (Imai et al., 2014).

The negative effect of the SO strategy and the positive effect of the SU strategy lead us to concur with Agarwal and Agrawal (2017) that the greatest poverty-reducing impacts in developing country rural areas is likely to occur through smallholder agricultural development, rather than through farm-exit. Our finding suggests that interventions for such impacts should not discount even the 'smallest of smallholders'. Such interventions should aim for improving access to lands and targeting broad 'livelihood outcomes', rather than narrow 'productivity/profitability' gains. Towards this, the promotion of 'diverse and complementary innovations', rather than a single technology, would be required. Development interventions also need to consider that the smallest of the smallholders are likely to be found closer to hazard hotspots, facing greater risk of exposure-damages from climatic changes, and thus stepping out of farming. To prevent this, and to promote agricultural upliftment, adequate credit, and improved and well-targeted extension services should be made accessible for them.

Sensitivity would be required in communication strategies. For example, too much emphasis on climatic risks may discourage very small farmers from uplifting their agriculture and encourage them to step-out. In such a context, a positive framing of climate change communication – containing messages of opportunities and hopes, rather than of dooms and despair – may be useful. It is such 'tailoring' of psychological-institutional drivers that is likely to deliver desired outcomes.

CRediT authorship contribution statement

Md. Mofakkarul Islam: Conceptualisation, Methodology, Data curation, Formal analysis, Writing – original draft, Writing – reviewing and editing, Project administration, Supervision, Funding acquisition. **Md. Asaduzzaman Sarker:** Investigation, Data curation, Writing – Original draft, Project administration, Supervision. **Md. Abdullah Al Mamun:** Investigation, Data curation, Formal analysis, Writing – original draft. **Md. Mamun-ur-Rashid:** Investigation, Data curation, Formal analysis, Writing – original draft. **Debashis Roy:** Investigation, Data curation, Formal analysis, Writing – original draft.

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.

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Appendix A: Path diagrams

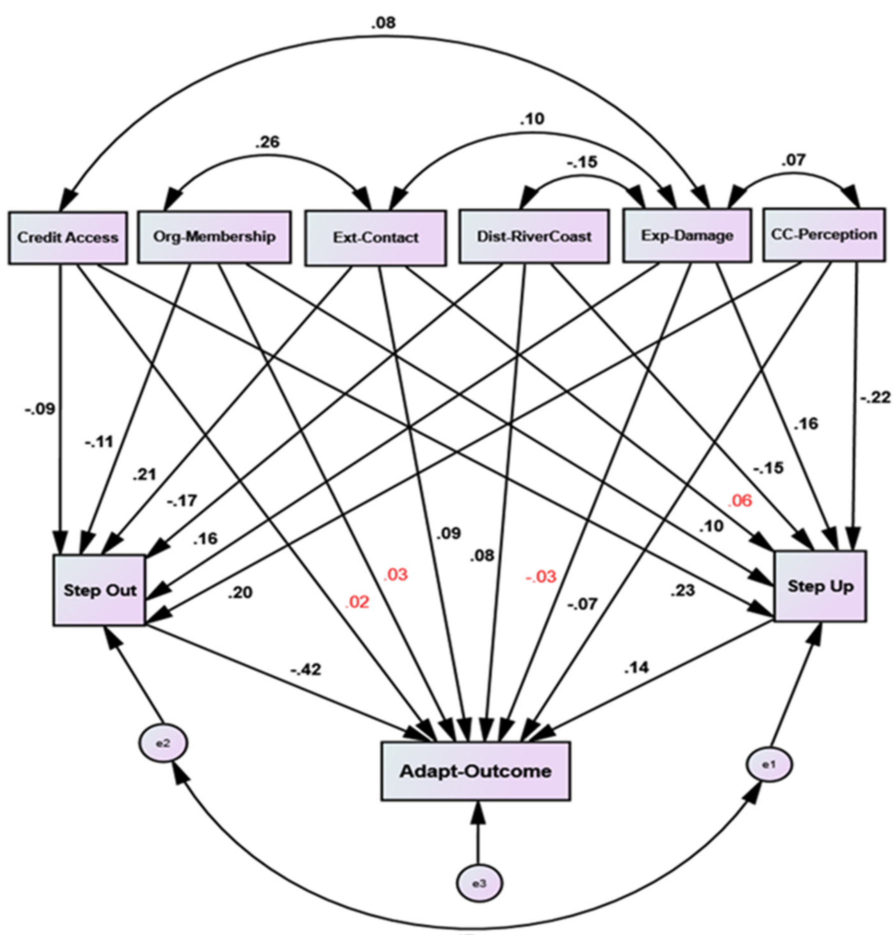

Fig. A1. Path diagram for the overall model (standardised coefficients: black font = statistically significant; red font = non-significant)

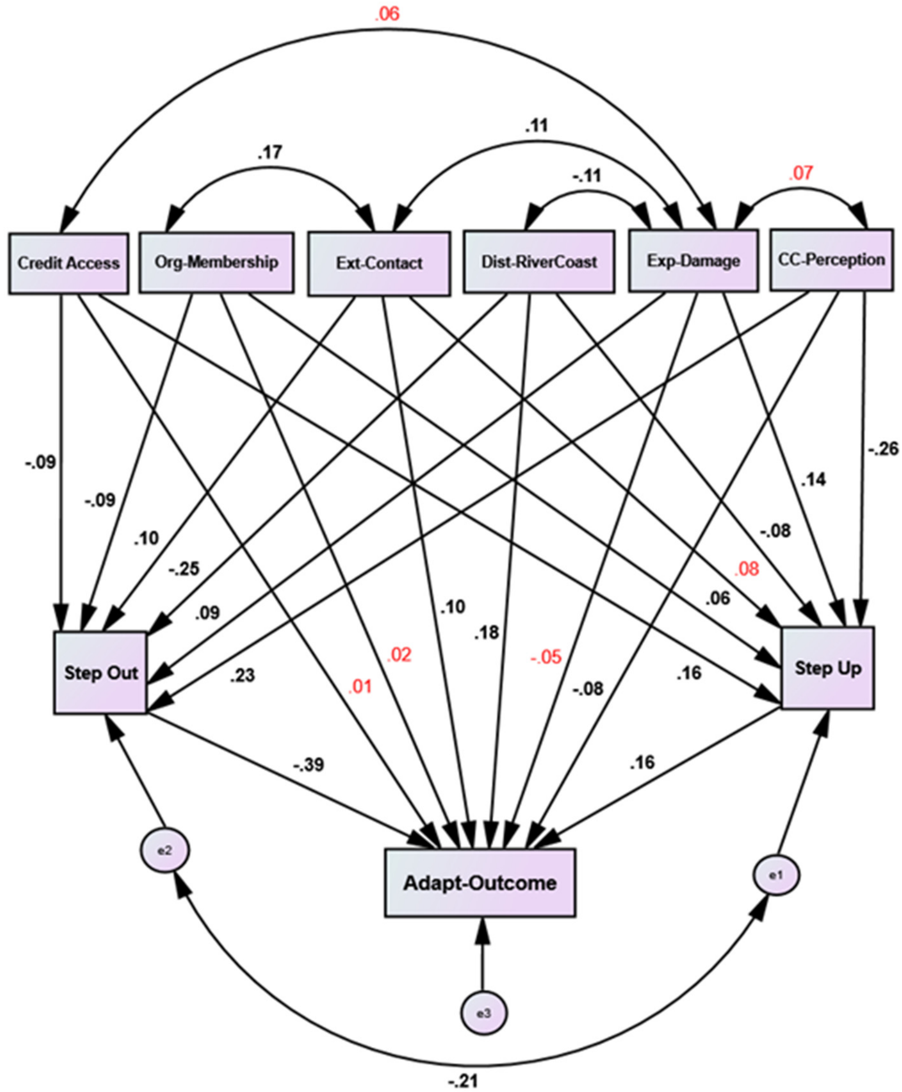

Fig. A2. Path diagram for the small landholder model (standardised coefficients: black font = statistically significant; red font = non-significant)

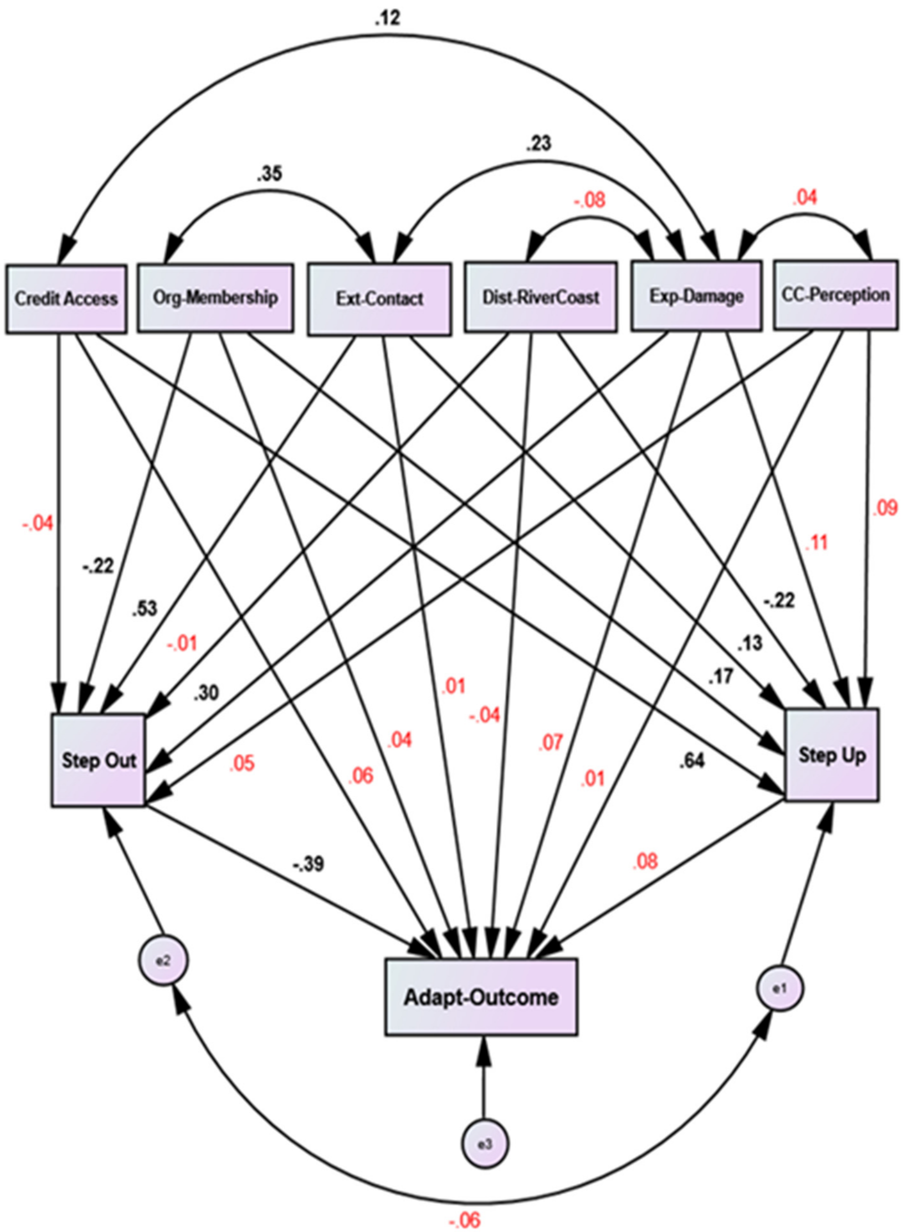

Fig. A3. Path diagram for the medium landholder model (standardised coefficients: black font = statistically significant; red font = non-significant)

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2021.105671.

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