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Crop resistance and household resilience – The case of cassava and sweetpotato during super-typhoon Ompong in the Philippines

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ABSTRACT

Extreme weather events can have devastating effects on agricultural production. As rural households in developing countries largely depend on agriculture, climatic shocks have the potential to undermine food security. In this paper, we explore how crop resistance contribute to household resilience in extreme weather events. As case study, we used cassava and sweetpotato, two root and tuber crops (RTCs), in the context of super-typhoon Ompong that wreaked havoc in the northern parts of the Philippines in 2018. Primary data were collected from 423 households who were affected by the super-typhoon. Methodologically, we employed a multivariate probit model to jointly estimate various household disaster responses, and applied propensity score matching techniques to control for potential endogeneity. The findings suggest that RTCs can contribute to households' resilience capacity due to their resistance to climatic shocks being underground crops. In addition, RTCs appear to be important in influencing the households' responses to typhoon. Our findings suggest that RTC cultivation reduces the need to resort to negative coping strategies, such as using household savings and requesting assistance from neighbors and friends, and that higher consumption of sweetpotato is linked to longer spells of reduced mobility. Furthermore, in the case of super-typhoon Ompong, affected households exploited the short production cycle of sweetpotato and cassava and planted them in the typhoon aftermath, a strategy that helped to gain faster access to food. Based on these findings some policy recommendations are proposed.

1. Introduction

Extreme weather events have become more frequent during the past decades, having a plausible link with climate change [1–4]. In particular, in the Asia-Pacific region, tropical typhoons have become recurrent events which are projected to be more intense in the future [5].

The effects of tropical typhoons are manifold. Strong winds, heavy rainfall, storm surges, and landslides affect people's livelihoods and their environment in various ways. In the worst case, a typhoon results in human casualties [6]. Public infrastructure is frequently affected as typhoons damage local bridges and roads, hindering access to villages and markets while damaged power grids can result in temporary power cuts [7]. Excess water from heavy rainfall causes landslides and river levels to rise to an extent that can breach their banks, resulting in flooding even much further downstream from the area directly hit by the typhoon [8,9].

The effects of typhoons can be particularly disastrous for rural resource-poor households who still largely depend on agricultural production and natural resources for food and incomes [10], with the extent of damages depending on frequency, intensity, and track of the typhoons [11]. On the day of impact, heavy rainfall and strong winds damage crops resulting in a partial or complete loss of harvest. Afterward, it takes several days for the water to recede from the agricultural land, which may further damage crops. Typhoons thus contribute to food insecurity as quantities and quality of food produced for household consumption and for sale are reduced. Reduced mobility and limited market access can result in further income cutback and subsequent inability to purchase other food items [12–14].

Households affected by disasters frequently engage in coping strategies which include resorting to household's savings, selling assets,

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taking out loans from banks, asking neighbors and family for assistance [15,16], migrating, and changing food consumption patterns [12,17], usually by reducing consumption of meat and other expensive food items.

While natural disasters can affect anyone, they have the potential to undermine food security especially for poor and vulnerable rural households who are frequently unable to bounce back effectively and efficiently due to the lack of resources, such as savings, off-farm employment, or social networks [18,19]. Although resource-wealthy households can also be hit hard because they generally possess more damageable assets than poor households [19–22], those wealthy households are often observed to recover quicker from shocks as they can rely on savings and off-farm incomes [21,23]. Finally, women are generally found to be more vulnerable than men in times of hardship as – primary care takers of the family – they often reduce their share of food intake to ensure that children or elderlies have enough to eat [24, p.58].

Root and tuber crops (RTCs) are key components of agri-food systems in the Asia-Pacific region, particularly in hill and coastal areas which are among the most exposed environments to climate change [22]. In these settings, RTCs are key crops for food security and mainstay of rural livelihoods, especially for the poorest communities in marginal lands and the indigenous people. Nevertheless, and despite their recognized capacity to withstand weather extremes [25], how RTCs are used strategically to prepare for, cope with, and recover from climatic shocks has not been thoroughly analyzed and documented. An improved understanding could inform preventive strategies, humanitarian interventions and policies to help rural households achieve and maintain food and nutrition security amidst climatic shocks.

The objective of this study is to analyze the ways RTCs can contribute to household resilience in face of climatic shocks. We adopt a definition of household resilience as the ability of a household to anticipate, prepare for, cope with and recover from shocks by deploying coping, adaptive, and transformative strategies [26]. Rather than investigating resilience as a whole, we focus on two important aspects: (1) resilience capacity which refers to the attributes, characteristics, and "capitals" households rely on when they are hit by a shock [23,27,28] and (2) coping strategies which affected households apply in the aftermath of a shock. We do so by analyzing crop resistance – what we refer to as the biophysical capacity of a crop to withstand impacts associated with climatic shocks, such as strong winds, heavy windfalls, and flooding – of RTCs and major crops. We then investigate how RTCs can influence household coping strategies applied in the aftermath of a shock.

Our aim is to contribute to the literature on disaster risk reduction by building on earlier studies on household resilience [26–30]. While there is growing consensus on the importance of agricultural crop diversity for rural household resilience [e.g., 29,30], much less is known about the role of crop choice and the inclusion of specific crops in household's portfolio of coping strategies. Our study contributes to fill this gap in resilience literature as it is among the first to analyze the influence of specific crop choice on household resilience capacities and coping strategies.

As case study, we use super-typhoon Ompong (internationally known as Mangkhut) that wreaked havoc in the northern parts of the Philippines in 2018. Generally, the Philippines faces a high risk of being affected by natural climate-related hazards because of its geographical location at the western side of the Pacific [31]. In particular, typhoons regularly land on the entire Philippine archipelago and especially on the northern island of Luzon [32,33]. In terms of crop focus, for this study we selected cassava and sweetpotato, the two main RTCs in the country.

The rest of this paper unfolds as follows. In section 2 we discuss RTC resistance and their contribution to the resilience of key agri-food systems in Asia amidst climate change and related shocks. In section 3, we present background informantion on super-thypoon Ompong. Next, we describe materials and methods succinctly in section 4. Section 5 presents the results which are further discussed in section 6. Finally, we draw several policy recommendations in section 8.

2. Literature review: resistance of root and tuber crops

Root and tuber crops which include potato, cassava, sweetpotato, and yams belong to different botanical families but are often grouped together as they all produce underground food and share other important characteristics. These crops are second in importance to cereals as global sources of carbohydrates [34], are key sources of micro-nutrients [35] and provide a range of income-generating opportunities in the food, feed and industrial sectors [36].

Latest estimates indicate that RTCs occupy approximately 62 million hectares worldwide and produce 832 million tons annually [37]. Many of the developing world's poorest producers and consumers depend on RTCs as an important source of food, nutrition and income [38,39]. This is reflected in the relative contribution of different regions, with the Asian and African regions representing 40% and 37% of global production, respectively [37]. Potato, sweetpotato, and cassava account for almost 90% of global RTC harvest [37], rank among the top ten food crops produced in developing countries [36,40], and are suitable for sustainable intensification [41].

The importance of RTCs for diverse populations and ecologies in Asia has been widely documented [42–45]. Based on an extensive review of literature, Prain and Naziri [22] identified three major agri-food systems in Asia to which RTCs contribute in different ways as staple or complementary food, economic resources and cultural signifiers. They include the ancient shifting cultivation system ('slash and burn') widely present in the tropical and sub-tropical hill areas of Asia; the cultivation of RTCs as rotation or relay crops in rice-based systems primarily in lowland flood plains and coastal areas; and the inclusion of RTCs in rural and urban home gardens. Naturally suited to tropical agro-climatic conditions, RTCs require less-intensive management and can grow with little or no artificial input, making them suitable for cultivation in less productive and marginal lands [46]. They are often grown in mixed-farming systems. Because of their broader adaptation, flexible planting and harvesting times, and in-ground storability, these crops contribute to food diversification over an extended period of time and provide food during lean seasons, thus mitigating the shortfall of staple crops [34]. Sweetpotato is drought tolerant [47] and the perennial character of the crop contributes to food security. In comparison to other important food crops, roots can be harvested after only 90–110 days, providing early availability of food and opportunity for marketing, which can help smoothing crisis impacts [48]. Furthermore, the roots can be piecemeal harvested for up to five years in shifting systems, and vines can be easily multiplied as planting material, thus enhancing further the benefits of the crop [49–51]. Like sweetpotato, cassava has a broad adaptation to different environments and because of its deep rooting systems can escape drought and is cultivated in areas where few other crops would survive [47,52]. The crop has no fixed period of maturity, but needs 7–18 months to produce commercial roots depending on varieties and conditions. Also, like sweetpotato, it is a perennial crop, although often grown as an annual, and can be piecemeal harvested for subsistence purposes [53]. Finally, the ability of RTCs to tolerate heat and, for some varieties of sweetpotato, salinity, also explains why these crops are considered 'climate-smart'.

Recent studies suggest that the contribution of RTCs to global food security and poverty reduction is likely to increase in the face of climate change [54]. A key process, as a result of climate change, will be crop substitution. Projections indicate that, under different future climatic scenarios, RTCs will likely replace more sensitive cereals, like rice and maize, in several Asian countries [55].

Besides their contribution to the resilience of Asian agri-food systems to long-term effects of climate change, and central for this study, RTCs are key 'survival crops' in times of climatic shock, such as typhoons. Analyzing the effects of typhoons is relevant for Asia because , unlike in Africa and Latin America, storms and floods are the disasters mostly responsible for reduced agricultural production [56]. In vulnerable environments of Asia, when paddy fields are damaged and rice yields reduced, RTCs are important food sources as farmers have assurance that they would still have foodstuffs to harvest for consumption or sale [57,58]. The low-growing habit of sweetpotato, particularly in spreading varieties, helps the crop to withstand typhoons [59]. According to Lebot [60], sweetpotato has often been a lifesaver; for example, it saved the Japanese nation when typhoons destroyed all their rice fields just before World War I. In the aftermath of recent cyclones and typhoons that decimated eastern India and the central Philippines, sweetpotato was one of the few crops able to continue supplying food to local populations [61,62]. Particularly in areas most devastated by Yolanda, a super-typhoon that hit the Philippines in 2013 causing over 6,000 casualties and a combined damage and loss to agriculture amounting to over USD 1.4 billion [56], only sweetpotato was marginally affected in fields amidst 95% fallen coconuts (combined damage estimated at USD 688 million) and other trees, and dried up grain fields. Also in central coastal regions of Vietnam, sweetpotato plays a key role as a buffer food crop in case the rice harvest is affected by typhoons [63]. Due to high resistance, in typhoon-prone areas sweetpotato is often preferred as a food crop over maize which is susceptible to strong winds [64].

Unlike sweetpotato, cassava is susceptible to strong winds which can cause lodging of the plants, resulting in severe root damage. However, farmers who anticipate the arrival of a typhoon can minimize the damage by cutting off the stems above ground-level. Most importantly, cassava can be stored in the ground for two to three years, providing some insurance against these calamities - as long as these do not occur early on in the growing cycle - and, like sweetpotato, cassava can be planted at any time of the year [59].

Finally, RTCs play an important role not only in short-term responses to typhoons but also in longer-term adaptive strategies. For instance, households most affected by recent calamities in India and Philippines were reported to start planting RTCs, particularly short- durationsweetpotato varieties, in the first weeks after the event for securing fast access to food. In fact, in the Philippines, in the years following the typhoon, the planting of RTCs has expanded from backyard gardens to hillsides [22]. Cognizant of the importance of reestablishing seed systems in post-shock recovery, the Government of the Philippines engaged in distribution of sweetpotato planting material as part of the post-Yolanda rehabilitation effort [61]. While this is not a common practice in post-disaster interventions, examples exist for similar intervention. For example, the Government of Mozambique also distributed free sweetpotato planting materials following the devastating floods that affected the country during theearly 2000s [65].

Against this background, we formulated the hypothesis that RTCs are more resistant to extreme whether events than aboveground crops. We further hypothesize that households who had RTCs in the field prior to the typhoon were better prepared and able to use these crops as part of their response – either consuming them directly or selling them for income – while the farmers who did not have RTCs had to rely on other types of responses (including some negative coping strategies). In short, we predict that households who grew RTCs before the typhoon were able to bounce back better and faster. Finally, we hypothesize that affected farmers would increase future planting of RTCs as part of either their short-term recovery or long-term transformative strategies.

3. Background

The northern island of the Philippines, Luzon, has been frequently affected by extreme weather events. Super-typhoons Pepeng (internationally known as Parma) in 2009, Haiyan (Yolanda) in 2013, and Lawin (Haima) in 2016 are recent examples Super-typhoon Ompong (Mangkhut), the study case for this research, made landfall in the Cagayan province of Luzon Island on September 15, 2018, at 1:04 a.m. local time, [66] (see Map 1). This typhoon was identified as the strongest typhoon to hit the country since Haiyan (Yolanda) which caused extensive damages in 2013 [67].

In the short passing of a single day, Ompong had a devastating impact across several regions in Northern and Central Luzon. Ilocos and Cordillera Administrative Region (CAR) were the most affected regions and experienced a 4-day rainfall that was 39.1% higher than the typical amount for the whole month of September. On September 15 alone, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) recorded 535 mm rainfall for the CAR. This surpassed the recorded rainfall during the passage of typhoon Ondoy (Ketsana) that resulted in massive flooding and landslides within Metro Manila in 2009 [68]. Due to rugged terrain of Northern Luzon, heavy rainfall caused flooding and landslides in 402 areas, especially in CAR [69].

According to the Philippine National Disaster Risk Reduction Council [66], about 800,000 households were affected, 82 persons were killed and 138 injured, mainly due to landslides, and two persons remained missing. Overall, it was estimated that the flooding and landslides generated USD 493 million damage on agriculture. Additional damage on infrastructure totaled USD 128 million with flood control structures, roads, bridges and public buildings being partially or totally destroyed, leading to a total estimated damage of USD 620 million. In CAR only, 171,000 farming households with a total of 140,000 ha of agricultural areas were affected [69,71]. Farming households incurred major agricultural losses for the two most important commercial crops: maize (USD 51 million) and rice (USD 27 million). Other high value commodities such as vegetables and fruit crops (USD 7 million), and livestock (USD 0.45 million) were also affected [66].

4. Materials and methods

4.1. Conceptual framework

To help structuring our analysis and in particular to assess the contribution and role of RTCs to the resilience of households and communities affected by typhoons, we rely on some of the most recent progress that has been made in the literature on resilience in the context of humanitarian and food security crises [27,28,72,73]. While several resilience indexes have been proposed in the literature in relation to disasters [e.g., see 74], we use the conceptual framework developed by Béné et al. [75; cf. their Fig. 1, p.155]. According to these authors, households and communities are characterized by specific (socio-economic) attributes, assets and "capitals" such as their income and savings, their access to information, social capital (friend/family network), level of education, size of household, livelihood strategy, etc. Those are the attributes (also called resilience capacities) which they rely on when they face a shock [23,27,28]. In our case, one additional attribute of interest will be whether these households cultivate RTCs, in particular cassava and sweetpotato.

When people are affected by long-term changes or by stressors (e.g., increase in frequency or length of drought), or when they are hit by shocks (such as a typhoon or a flooding event), they put in place specific strategies which can be anticipative responses (i.e., ex ante) or reactive responses (i.e., ex post) [76,77]. Some of those responses will turn out to lead to "positive" outcomes (for instance, when they help households mitigate the direct impact of a shock and bounce back faster) [73]. Those would include adaptive responses – those which help households and communities to adapt to changes in the longer-term, or even to transform by addressing some of the structural causes of vulnerability – e.g., gender inequity [74,76]. Some other responses are less positive in that they may lead to more detrimental consequences in the short- or longer term. Those negative coping strategies include reducing food consumption or expenses, or selling productive assets [15,16,76].

In sum, the household's ability of handling a specific shock depends not just on the severity of the initial shock, but also on the resilience capacities of the household and the type of coping, adaptive, and transformative strategies that it put in place (in anticipation and/or in response to a particular shock) [26], which eventually determines the

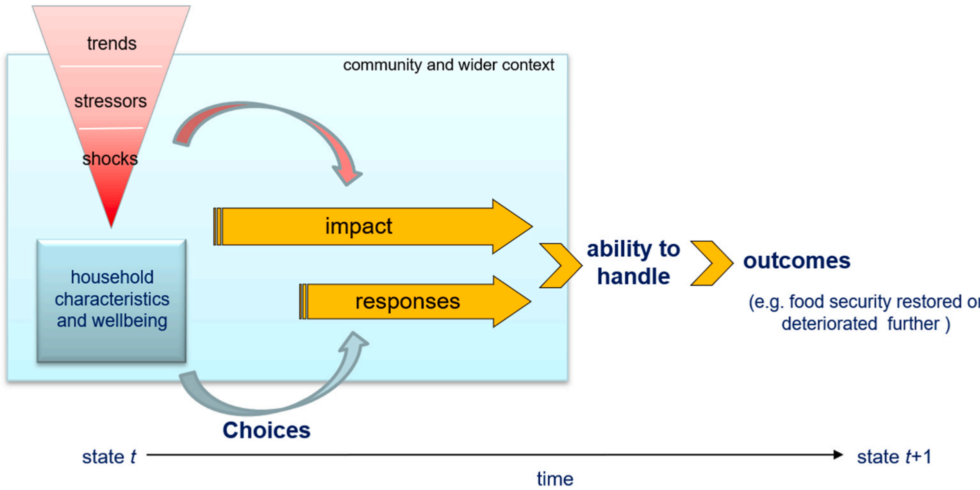
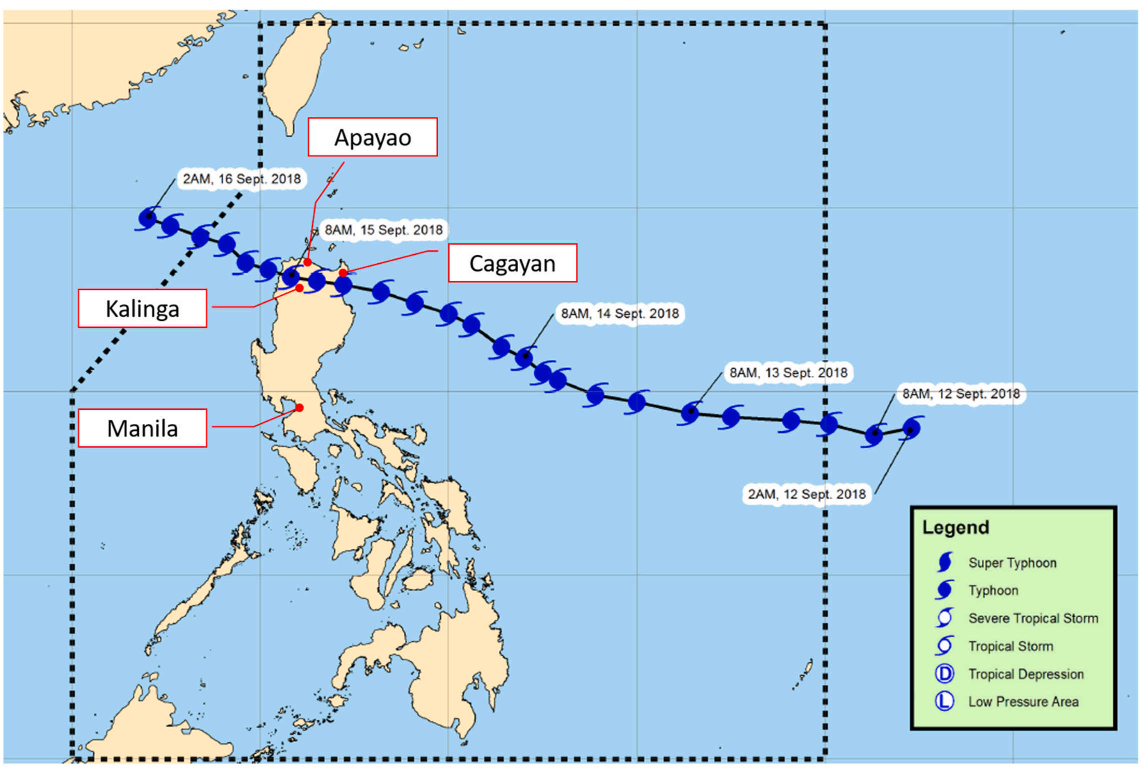


Fig. 1. *Conceptual Framework.*
Source: Béné et al. [75].



Map 1. Track of super-typhoon "OMPONG" in 2018.
Source: adapted from Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) [70].

level of wellbeing of the household. For the purpose of this study, this level of wellbeing can be related to food security (Fig. 1). For instance, two households living in the same village, with the same initial levels of income, saving, education and social network and hit by the same shock (e.g., typhoon), could end up on two totally different trajectories of recovery, not because of the shock they faced or their initial resilience capacities (which were similar), but because of the type of responses they adopted: the first household members (who wanted to keep their saving for the daughter's forthcoming wedding) had no choice but to sell part of their productive assets to make up for the income drop. Once the money from the selling was exhausted, they progressively fall into poverty and face food insecurity. The other household had decided to use their savings to buy and plant short-cycle crops which allowed them, eventually, to bounce back and recover.

4.2. Sampling and data

A survey was conducted in the CAR of Luzon, Philippines. The research area was located in the (broader) corridor of super-typhoon Ompong. In this region, we selected two provinces, Apayao and Kalinga. Apayao is further north and located in the broader impact corridor, while Kalinga is located in the eye of the super-typhoon (see

Map 1). In both provinces, we further purposively selected five municipalities on the basis of their involvement in an ongoing IFAD investment project entitled "Integrated Natural Resources and Environmental Management Project" (INREMP) which was implemented by the Philippine Department of Environment and Natural Resources (DENR). In Apayao, which consists of seven municipalities, the municipalities of Conner and Kabugao were selected; in Kalinga, which consists of eight municipalities, Pinukpuk, Tabuk, and Tanudan were selected. To account for the higher number of municipalities, one additional municipality was selected in Kalinga. Collaboration with INREMP was a clear advantage to ensure smooth implementation of research activities on the ground (e.g., connect with village leaders, logistics, etc.).

For this study and given our budget, we randomly selected a total of 440 households affected by the typhoon. 20 households were randomly selected per barangay – the smallest administrative division in the Philippines – mainly for logistical purposes and from existing household lists. This resulted in the selection of 22 barangays which were randomly selected from barangay lists with INREMP activities. In using sampling proportional to size method, we oversampled barangays in Kalinga (N = 14) compared to Apayao (N = 8). Survey challenges (e.g., household identification, household willingness to participate), however, resulted in 19 households being effectively surveyed per barangay. Overall, this resulted in a total of 423 households included in the study.

Data collection took place between February and March 2019, five months after Ompong struck. For ethical consideration, we refrained from starting survey activities earlier to allow farming households to recover, at least partially. The timing of data collection was agreed on in consultations with DENR.

4.3. Modelling responses to shocks

To analyze the extent to which RTCs contribute to household resilience, we introduced a set of dummy variables which reflect a household's crop choice before the typhoon hit. We focused on cassava and sweetpotato as these are the two most important RTCs in the study region. This resulted in four distinct categories of farmers in our sample: households who, at the time of the typhoon, cultivated (i) sweetpotato but not cassava, (ii) cassava but not sweetpotato, (iii) both cassava and sweetpotato, and (iv) neither cassava nor sweetpotato. The latter group serves as the reference or counterfactual showing a scenario of how a household would have responded and recovered from a shock in the absence of cassava and sweetpotato cultivation.

As discussed in our conceptual framework, households can choose between various responses to mitigate climatic shocks, many of which found in resilience literature [35,77]. In this research, we added additional responses related to the consumption and planting of RTCs, specifically cassava and sweetpotato. When deciding on the responses to be deployed, typhoon-affected households may simultaneously decide between various options. In other words, the response decisions are not mutually exclusive and thus the unobserved heterogeneity captured in the various error terms are likely correlated. Whereas several separate probit regressions may result in biased estimates, for this study, we employ multivariate probit regression techniques. These allow for the correlation between the error terms by estimating the disaster responses as a system of equations. More formally, we can write [78]:

$$Resp\_X_{ij} = \beta_j Crop_{ij} + \gamma_j X_{ij} + \delta_j Tattribute_{ij} + \varepsilon_{ij} \tag{1}$$

where.

$Resp\_X_{ij}$ $(j = 1, \ldots, 6)$ represent six different disaster responses the *ith* household $(i = 1, \ldots, 423)$ can choose from to mitigate the impact of the typhoon. $Resp\_X_{i1} = 1$ if household *i* used household savings (0 otherwise); $Resp\_X_{i2} = 1$ if household *i* asked neighbors/friends for assistance (0 otherwise); $Resp\_X_{i3} = 1$ if household *i* consumed sweetpotato more than usual during first four weeks after Ompong (0 otherwise); $Resp\_X_{i4} = 1$ if household *i* consumed cassava more than usual during first four weeks after Ompong (0 otherwise); $Resp\_X_{i5} = 1$ if household *i* planted sweetpotato during first four weeks after Ompong (0 otherwise); and $Resp\_X_{i6} = 1$ if household *i* planted cassava during first four weeks after Ompong (0 otherwise).[1]

$Crop_{ij}$ $(j = 1, \ldots, 4)$ represent four different household crop choices the *ith* household $(i = 1, \ldots, 423)$ made before Ompong. $Crop_{i1} = 1$ if household *i* cultivated sweetpotato but not cassava when Ompong hit (referred to as "SP-only" in the remainder of this paper) (0 otherwise); $Crop_{i2} = 1$ if household *i* cultivated cassava but not sweetpotato when Ompong hit ("C-only") (0 otherwise); $Crop_{i3} = 1$ if household *i* cultivated both cassava and sweetpotato when Ompong hit ("SP & C") (0 otherwise).[2] Finally, $Crop_{i4} = 1$, if household *i* cultivated neither cassava nor sweetpotato when Ompong hit ("no SP & no C″) (0 otherwise). This last group is the reference or counterfactual group and estimation results are thus not produced by the model

X_{ij} is a vector of household-level control variables, which includes the number of household members, years of education of household head, age of household head, gender of household head (1 = male; 0 = female), marital status (1 = married; 0 otherwise), owned land area (log) and income in 2017 (log). Income for 2017 (rather than 2018, i.e., before the shock) is included in the regressions to avoid issues of reverse causality. Income is defined as monetary gains from agricultural production, off-farm activities, and remittances accumulated by all household members in a given year. The selection of the variables follows recent studies on household resilience [e.g., 28].

$Tattribute_{ij}$ is a vector of typhoon-related continuous variables which includes typhoon duration measured as the number of days of heavy rainfall and strong winds experienced by the *ith* household $(i = 1, \ldots, 423)$ and inability of households to reach local markets.

β_j, γ_j and δ_j are the unknown parameters which are estimated using maximum likelihood estimation techniques.

ε_{ij} is a random error term which captures unobserved heterogeneity of the *ith* household. We assume that the error terms (across $j = 1, \ldots, m$ alternatives) are multivariate and normally distributed with mean vector equal to zero.

All estimations were performed using robust standard errors to allow for potential heteroscedasticity and we only report marginal effects.

4.4. Endogeneity

The cultivation of cassava and sweetpotato prior to the typhoon likely occurred in a non-random manner. This means that various confounding factors might have influenced the adoption of those crops. These same factors might have, likewise, influenced the household's disaster responses, which could result in biased estimates. Various econometric estimation techniques (e.g., Heckman selection model, recursive bivariate probit, propensity score matching (PSM), etc.) can be used to control for the endogeneity caused by self-selection. Usually, a valid instrument is identified and included in the model. However, given our limited dataset it was not possible to identify such an instrument. We therefore dealt with endogeneity by using PSM techniques [79,80]. PSM is frequently used in impact assessment studies, including in studies on disaster risk management [see e.g., [32,81]. Note that PSM cannot control for unobserved endogeneity (e.g., risk aversion, crop preferences, etc.) which will remain a limitation of this study.

Empirically, household disaster responses were estimated by

[1] There are other important disaster responses not included in the multivariate analysis because of small N. These are taking out loans (N = 27), selling assets (N = 11), temporary migration to send remittances (N = 1), and reduce off-farm work to rebuild house/farm (N = 28).

[2] We observe that this respondent group (i.e., SP & C) only has 31 observations. For the further analysis, we thus decided to refrain from interpreting any results related to this respondent group. In all regression models, this respondent group is included.

Table 1
Descriptive statistics by respondent group.

Variable	Total (n = 423)	SP only (n = 136)	C Only (n = 89)	No SP & no C (n = 167)	T-test	
		(1)	(2)	(3)	(1)–(3)	(2)–(3)
HH members (#)	5.68	5.61	5.69	5.66		
Children under 5	0.27	0.29	0.31	0.25		
Children under 2	0.22	0.23	0.22	0.19		
Male	0.94	0.92	0.94	0.94		
Married	0.83	0.78	0.92	0.82		
Age (years)	49.00	51.00	47.83	46.68		
Education (years of schooling)	7.79	7.58	7.18	8.18		**
Occupation: farming	0.85	0.89	0.87	0.83	*	
Occupation: wage	0.73	0.84	0.77	0.68	**	
Total Income in 2018 (PhP)	66,678	75,176	62,884	55,500	**	
Agricultural production (PhP)	20,985	22,508	22,927	18,167	**	**
Off-farm employ. (PhP)	34,616	44,324	28,940	28,513	**	
Remittances (PhP)	5416	5022	5044	4611		
Savings (PhP)	4660	3321	5971	4209		
Agricultural production (dummy)						
Rice	0.75	0.88	0.63	0.71	***	
Maize	0.37	0.29	0.45	0.43	***	
Banana	0.43	0.40	0.49	0.41		*
Cassava	0.28	0	1	0		
Sweetpotato	0.39	1	0	0		
Taro	0.37	0.16	0.34	0.54	***	***
Yam	0.06	0.03	0.06	0.07	**	
Agricultural area (in ha)						
Total area[1]	0.96	0.78	1.15	0.96	**	*
Rice[1]	0.61	0.55	0.65	0.63		
Maize	0.72	0.58	0.99	0.65		*
Banana	0.26	0.09	0.27	0.36	*	
Cassava	0.067	0	0.07	0		
Sweetpotato	0.036	0.04	0	0		
Taro	0.087	0.12	0.13	0.06	**	***
Yam	0.124	0.06	0.32	0.07		***

Notes: [1]two outliers are not included where rice area >75 ha; * significance at the P < 0.1 level; ** significance at the P < 0.05 level; *** significance at the P < 0.01 level. SP: sweetpotato; C: cassava.

comparing adopters of sweetpotato (SP-only) and cassava (C-only), respectively, to a matched control group while accounting for the potential effects of confounding factors. The earlier model specification presented in equation (1) remains the same but the use of matching techniques allows for the comparison of outcomes (i.e., disaster responses) among treated (adopters) and non-treated (control) units to estimate the effect of the treatment which reduces the bias due to confounding factors [82]. Technically, the PSM results are expressed as Average Treatment Effects on the Treated (ATT) which computes the average differences in outcomes of adopters with and without a technology (i.e., cassava, sweetpotato). As we do not observe outcomes of adopters without a technology, a matched sub-sample of non-adopters is created using a set of observable characteristics which serves as the control group. We used the 'nearest neighbor' as the primary PSM algorithm and the 'radius' with radius (0.1) and 'kernel' algorithms as secondary strategies. All standard errors were bootstrapped with 1,000 replications.

5. Results

5.1. Household characteristics

The average household in the sample had about 5.7 members. Amongst those households, 27% had children under five years of age and 22% children under 2 years of age. Almost all households (94%) were male-headed and 83% of respondents were married at the time of the interviews. Respondents were on average 49 years old and had 7.8 years of formal education with most of respondents having attended elementary (38%) and high school (31%). Only some 4% of respondents were illiterate. Farming was the primary occupation for 85% of households and the second most important occupation was wage labor (73% of households), either off or on-farm (Table 1).

In 2018, annual household income and savings averaged PhP 66,678 (or USD 1,282),[3] to which off-farm employment contributed 52% (PhP 34,616), agricultural production contributed 31% (PhP 20,985), remittances contributed 8% (PhP 5,416), and savings contributed 7% (PhP 4,660).

In terms of agricultural production, the seven most frequently cultivated crops were rice (75% of respondents), banana (43%), sweetpotato (39%), taro and maize (37%), cassava (28%), and yam (6%). This confirms that RTCs – cassava, sweetpotato, taro, yam – are important but not primary crops in the study region. The relative importance of crops changes, however, when looking at area under cultivation. Households owned on average 0.96 ha of agricultural land, of which rice farming remained the most important, being cultivated on an average of 48% of the total land (0.46 ha). The second most important crop in terms of area was maize which was cultivated on an average of 0.27 ha of land, followed by taro (0.03 ha), cassava (0.019 ha), sweetpotato (0.014 ha), and yam (0.007 ha). The relatively small area under RTCs suggests that these crops were mainly cultivated in home gardens for household consumption rather than market purposes.

A deeper descriptive analysis reveals that respondents had distinct crop preferences. First, rice or maize were the main crops (as suggested by the negative correlation between the two crops shown in Table A1 in the Appendix). If households engaged in rice farming, their most preferred complementary crop was sweetpotato; rice cultivation was negatively correlated with all the other aboveground (i.e., banana, maize) and underground crops (i.e., taro, cassava). In turn, households who grew maize preferred banana as secondary crop.

Breaking down the total sample by respondent group reveals socio-economic differences (Table 1). For instance, households who only

[3] USD 1 equaled PhP 52 at the time of the survey.

cultivated cassava (C-only) had significantly fewer years of education compared with the counterfactual group (no SP & no C). In addition, households that only cultivated sweetpotato (SP only) were significantly more engaged in farming as primary occupation and wage labor as secondary occupation than the counterfactual group. This is confirmed by the significant differences observed for incomes derived from agricultural production and off-farm employment between the same respondent groups. Total annual incomes and savings in 2018 were, as a result, significantly higher. In terms of agriculture area, we observe that SP-only group had, on average, significantly less agricultural land (0.78 ha) and C-only group significantly more agricultural land (1.15 ha) compared with the counterfactual group (0.98 ha).

The respondent groups had different crop preferences. For instance, in the SP-only group there were significantly more rice growers (88%) but fewer maize growers (29%) compared with the counterfactual group (71% for rice and 43% for maize). In contrast, households in the C-only group cultivated slightly but significantly more bananas (49%) compared with the counterfactual group (41%). Despite the observed crop preferences, the area planted to rice was similar across respondent groups. For maize cultivation, we observe, however, a significant difference between C-only group (0.99 ha) and counterfactual group (0.65 ha).

5.2. Typhoon impacts

In the study area, farmers reported that Ompong brought heavy rainfall and strong winds that lasted for 2.6 days on average. While most of the households experienced two days of heavy rainfall and strong winds, 16% of the total sample (N = 66) experienced extreme weather for five days. As a result, in 30% of the cases (or N = 130) farmer fields were flooded. In these cases, excess water originated from heavy rainfall (N = 46), rivers (N = 3), or both (N = 81) and caused fields to be flooded for four consecutive days on average. The typhoon also brought about landslides which affected farmers' houses and fields. Some 34% of the sample (N = 144) experienced more than one landslide, four landslides being the maximum reported by two respondents. Furthermore, more than 50% of the sample (N = 226) experienced a reduced access to markets as a result of impassable roads – e.g., being flooded or blocked by fallen trees or other large debris – and destroyed bridges. In this case, households experienced on average four days of reduced mobility, the minimum being one and the maximum being 24 days (Table 2).

5.2.1. Typhoon impacts on household assets

Damages caused by Ompong spread across different aspects of people's livelihoods. Durable goods, such as farming/productive and household assets, were severely damaged. Hand tractors were damaged the most (20% of respondents who owned one) but only a few respondents owned one. Television satellite dishes, owned by about 60% of the respondents, were damaged in 10% of the cases. Almost every respondent had access to electricity (97%), 72% of whom experienced power cuts, for an average of 33 days.

Dwellings and houses were damaged substantially. The roofing which was usually made of galvanized iron sheets (96% of respondents) was damaged in almost half of the cases. As for the housing walls, wood was the most common material used by 45% of the respondents and damaged in 12% of the cases. Less commonly used bamboo and galvanized iron sheets were damaged considerably more often (in 62% and 100% of the cases) while stone walls were not damaged at all. Finally, if respondents had glass windows (20% of respondents), in 25% of the cases those were damaged (Table 3). All other household assets incurred only minor damages (Table 2A).

Table 2
Typhoon duration indices experienced by respondent.

Variables	Obs.	Mean	Std. dev.	Min	Max
Strong wind and heavy rainfall (# days)	423	2.57	1.21	1	5
Field flooded (# days)	130	4.04	3.02	0.5	10
Landslides (#)	144	1.19	0.57	1	4
Reduced mobility (# days)	226	3.96	2.77	1	24

Table 3
Selected assets and housing material and damages by Ompong.

Assets	Household ownership (%)	Damaged (%)
Hand tractor	1.2	20.0
TV (with satellites)	60.1	9.8
Electricity	96.7	71.9
Electricity disruption		32.7 (days)
Roofing		*46.1*
Galvanized Iron sheets	96	45.1
Wall		*12.3*
Stone	0.2	0.00
Wood	44.9	12.1
Galvanized Iron	0.2	100
Bamboo	5.7	62.5
Glass Windows	19.9	25.0

Table 4
Agricultural production in non-typhoon (2017) and typhoon year (2018).

Year	Agricultural production	Share of total income
	(PhP)	(%)
2017	35,927	44
2018	20,985	31
Difference 2018–2017	−14,942***	24

Notes: 1 USD equals 52 PhP at the time of the interview; ***statistically significant at $P < 0.01$.

5.2.2. Typhoon impacts on agricultural production

Agricultural production was considerably affected by Ompong. Comparing household agricultural incomes generated in the typhoon year (2018) with those generated in the year prior (2017) reveals a significant decline of 42%, from an average of PhP 35,900 (US$ 690) to PhP 21,000 (US$ 400) per household (Table 4). Though not entirely typhoon-related, the contribution of the typhoon is – at the very least – likely and mainly as result of substantial yield losses of aboveground crops. Almost every respondent who cultivated rice (97%), banana (95%), or maize (92%) reported crop losses due to Ompong. These losses were the highest for banana (77% of yield) and rice (51% of yield), followed by maize (48%) (Table 5). In contrast, RTCs, being underground crops, were considerably less damaged. The share of farmers reporting losses was 26% for yam, 19% for taro, 18% for cassava, and 14% for sweetpotato. In the case of reported losses, crop damages varied between 22% of yield losses reported for yam, 15% for cassava, 12% for taro, and merely 8% for sweetpotato (Table 5).

Table 5
Crop cultivation and crop losses.

	Share of farmers growing crops	Share of farmers reporting crop loss	Crop lost among affected farmers
Crop	(%)	(%)	Mean % (std dev)
Rice	75	97	51 (25)
Maize	37	92	48 (28)
Banana	43	95	77 (32)
Cassava	28	18	15 (35)
Sweetpotato	39	14	8 (24)
Taro	37	19	12 (29)
Yam	6	26	22 (41)

Table 6
Household responses to typhoon by crop category.

Proportion of farmers adopting responses	Total	SP-only	C-only	No SP & no C	T-test	
	(n = 423)	(n = 136)	(n = 89)	(n = 167)		
		(1)	(2)	(3)	(1)–(3)	(2)–(3)
Consume more sweetpotato	0.376	0.838	0.112	0.126	***	
Consume more cassava	0.189	0.118	0.483	0.042	***	***
Plant sweetpotato	0.586	0.404	0.596	0.701	***	**
Plant cassava	0.489	0.412	0.517	0.508	**	
Use savings	0.234	0.169	0.269	0.275	**	
Assistance from neighbors/friends	0.267	0.213	0.236	0.323	**	*

Notes: ***statistically significant at P < 0.01; **statistically significant at P < 0.05; *statistically significant at P < 0.1; 'C & SP' group results not shown.

5.3. Typhoon responses

During the first four weeks after Ompong, households applied various short- and long-term responses to cope with the typhoon impacts. Only a small fraction of respondents reported to have eaten a more limited variety of foods (5%), smaller portions (2%) or fewer meals (2%). A substantial amount of rice, the most important food crop, fortunately had already been harvested and stored when the typhoon made landfall and some was purchased afterward. However, a change in food consumption was observed as households reported to have consumed more sweetpotato (38%) and cassava (19%) than they would have eaten if Ompong had not hit (Table 6). This change in consumption behavior was much more pronounced among those households who had those crops in the field when Ompong hit.

Furthermore, in the immediate aftermath of the typhoon, about 60% of respondents planted sweetpotato, some 50% cassava, and 40% taro/yam. Interestingly, not only sweetpotato and cassava growing households planted sweetpotato (40% and 60%, respectively) and cassava (41% and 52%, respectively) after Ompong, but households which were not growing these crops (No SP & no C) at the time when Ompong hit also started growing sweetpotato and cassava (70% and 51%, respectively) (Table 6). Of those who planted RTCs, an average of 80% did so for home consumption and 20% for sale.

Besides an increase in consumption and planting of RTCs, asking neighbors for assistance and using savings were the two most common responses deployed by affected households. Asking neighbors and friends for assistance was reported by some 27% of respondents. Respondents growing either cassava or sweetpotato did so significantly less than the others. About 23% of households reported to have resorted to savings for recovery. Sweetpotato growing households used savings significantly less compared with those respondents growing neither cassava nor sweetpotato.

5.3.1. Results of multivariate probit model

First of all, the multivariate probit model was the correct choice because the null hypothesis of zero error term correlation can be rejected at the 1% significance level. The results describing the different household responses to the typhoon are shown in Table 7.

Controlling for key household characteristics and typhoon characteristics, the models suggest that households who had cultivated sweetpotato before Ompong hit were 72% more likely to also consume sweetpotato after Ompong compared with those households who had not grown sweetpotato or cassava (column 1). Similarly, cassava growing households were 52% more likely to consume cassava compared with households who had not grown sweetpotato or cassava. In addition, also sweetpotato growing households were 7.6% more likely to consume cassava (column 2). However, this coefficient becomes negative and significant in all three PSM estimation results (see Section 5.3.2).

In contrast, the negative and significant coefficient in column (3) suggests that planting sweetpotato as a coping strategy was applied 27% more often by households who did not grow sweetpotato or cassava before Ompong (the counterfactual group) than households who cultivated sweetpotato before Ompong. The control group was also 12% more likely to plant sweetpotato after Ompong compared with households who cultivated cassava before Ompong. For planting cassava as a coping strategy, the results are insignificant (column 4), most likely because of the longer time required for cassava to reach maturity.

Households who had grown sweetpotato before the typhoon were about 10% less likely to use savings and 12% less likely to ask neighbors for assistance (columns 5 & 6) compared to the counterfactual group.

Regarding demographic, socio-economic, and typhoon duration variables, most of these variables enter insignificantly into the model. A few of these control variables deserve attention. In particular, the variable related to annual household incomes in 2017 enters significantly in almost all regression estimations. For sweetpotato and cassava consumption as a coping strategy, the results suggest that wealthier households were more likely to consume sweetpotato and cassava. The insignificant interaction terms between income 2017 and crop categories further reveal that income explains consumption irrespective of having grown sweetpotato/cassava or not (columns 1 & 2 in Table 3A in the Appendix). Conversely, planting sweetpotato and cassava was a more likely coping strategy for resource-poor households (columns 3 & 4 in Table 7), irrespective of having sweetpotato or cassava in the field when the typhoon hit.

We further found that better-off households were significantly less likely to resort to savings (column 5), whereas income is insignificant in explaining resorting to neighbors' assistance (column 6). However, the interaction term results suggest that wealthier households who had sweetpotato at the time of Ompong were significantly less likely to resort to savings compared to households who had not grown sweetpotato or cassava at the typhoon event (column 5 in Table 3A).

Typhoon characteristics enter the model partly significantly in predicting coping strategies.[4] First, an additional day of household exposure to heavy rainfall and strong winds increased the likelihood by 3% that respondents asked neighbors or friends for assistance (column 6 in Table 7). Second, an additional day of reduced mobility (i.e., cut off from markets) increased the likelihood that households consumed sweetpotato (2.8%) or cassava (1.6%) after Ompong (columns 1 & 2).

5.3.2. Propensity score matching results

To account for potential endogeneity in crop choice, we applied PSM techniques. In doing so, we compare household responses of sweetpotato and cassava cultivating households, respectively, to a similar group matched on key observable characteristics. The intermediate calculations which include balancing property test estimations for each household response individually, are presented in the Supplementary Materials. The final PSM results using nearest neighbor algorithm are

[4] Due to the high significant correlation (0.53***) between duration of extreme wind and rain and experienced reduced mobility we refrained from including both variables jointly into the models to avoid multicollinearity. Reduced mobility can be perceived as a result of longer spells of exposure to heavy rainfall and strong winds and thus likely better predict reasons for households to rely on home consumption of sweetpotato and cassava. In turn, for the planting decision of sweetpotato and cassava the typhoon duration is likely more important than the reduced mobility because farmers may start planting right after the extreme weather passed whereas the repercussions of reduced mobility may last longer. For the variables 'using savings' and 'assistance neighbors' both typhoon control variables would be reasonable to include and we opted for typhoon duration.

Table 7
Estimated parameters for disaster responses.

	Consumption Sweetpotato	Consumption Cassava	Planting Sweetpotato	Planting Cassava	Use Savings	Neighbor assistance
Variables	(1)	(2)	(3)	(4)	(5)	(6)
SP-only	0.719*** (0.046)	0.076** (0.054)	−0.266*** (0.058)	−0.071 (0.059)	−0.095** (0.046)	−0.118** (0.047)
C-only	−0.029 (0.086)	0.522*** (0.071)	−0.118* (0.070)	−0.005 (0.067)	0.003 (0.054)	−0.086 (0.052)
HH size	−0.015 (0.014)	−0.007 (0.008)	−0.013 (0.012)	0.146 (0.097)	0.000 (0.009)	−0.017 (0.011)
Male	0.179 (0.099)	−0.070 (0.113)	0.006 (0.121)	−0.214* (0.111)	0.103 (0.073)	0.078 (0.093)
Age	0.003 (0.002)	0.000 (0.001)	−0.002 (0.002)	−0.001 (0.002)	−0.001 (0.002)	−0.001 (0.002)
Married	−0.105 (0.087)	0.056 (0.041)	0.052 (0.083)	0.199** (0.078)	−0.087 (0.073)	−0.000 (0.068)
Education (years)	0.004 (0.007)	−0.004 (0.004)	−0.002 (0.007)	0.004 (0.006)	−0.004 (0.005)	−0.005 (0.005)
Income 2017 (log)	0.160*** (0.029)	0.081*** (0.016)	−0.100*** (0.025)	−0.065*** (0.022)	−0.044** (0.017)	−0.016 (0.019)
Area (log)	−0.020 (0.023)	0.003 (0.016)	0.038* (0.025)	0.024 (0.024)	0.003 (0.021)	0.002 (0.022)
Wind/rain (days)			−0.019 (0.021)	−0.009 (0.021)	−0.004 (0.017)	0.033* (0.018)
R. mobility (days)	0.028** (0.010)	0.016*** (0.005)				
Pseudo R-squared	0.469	0.311	0.103	0.038	0.038	0.027
N			423			
Log likelihood			−1210.683			
Wald chi2 (64)			383.81			
Prob > chi2			0.00			

Notes: marginal effects; SP = sweetpotato, C = cassava; robust standard errors are presented in parentheses.
Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{51} = \rho_{61} = \rho_{32} = \rho_{42} = \rho_{52} = \rho_{62} = \rho_{43} = \rho_{53} = \rho_{63} = \rho_{54} = \rho_{64} = \rho_{65} = 0$, $chi^2_{(15)} = 158.313$, p-value = 0.000.
***significant at the 1% level; **significant at the 5% level, *significant at the 10% level.

Table 8
Propensity score matching results for average sweetpotato only category (SP-only) effect on disaster responses.

	ATT	t-value[a]	Number of treated	Number of control
Consumption of SP	0.640*** (0.066)	9.761	136	80
Consumption of C	−0.213*** (0.064)	−3.319	136	80
Planting SP	−0.096 (0.083)	−1.152	136	80
Planting C	−0.044 (0.085)	−0.518	136	80
Savings	0.088 (0.061)	1.441	136	80
Neighbor assistance	−0.044 (0.072)	−0.609	136	80

Notes: Bootstrapped standard errors in parentheses. Bootstrapping done with 1,000 replications. [a] 1% level one tailed test: *t*-critical value = 2.326; 5% level one tailed test: *t*-critical value = 1.645; 10% level one tailed test: *t*-critical value = 1.282; *** significance at the 1%-level. ATT: average treatment effect of the treated SP: sweetpotato; C: cassava.

Table 9
Propensity score matching results for average cassava only category (C-only) effect on disaster responses.

	ATT	t-value[a]	Number of treated	Number of control
Consumption of SP	−0.270*** (0.069)	−3.890	89	75
Consumption of C	0.438*** (0.062)	7.119	89	75
Planting SP	0.056 (0.090)	0.627	89	75
Planting C	0.011 (0.084)	0.134	89	75
Savings	0.067 (0.073)	0.922	89	75
Neighbor assistance	−0.011 (0.074)	−0.152	89	75

Notes: Bootstrapped standard errors in parentheses. Bootstrapping done with 1,000 replications. [a] 1% level one tailed test: *t*-critical value = 2.326; 5% level one tailed test: *t*-critical value = 1.645; 10% level one tailed test: *t*-critical value = 1.282; *** significance at the 1%-level. ATT: average treatment effect of the treated; SP: sweetpotato; C: cassava.

presented in Tables 8 and 9. Results for radius and kernel algorithm as presented in Tables 4A and 5A in the Appendix.

PSM results show that consumptions of sweetpotato and cassava were significantly higher when these crops were planted before Ompong, compared with the matched control group. In turn, sweetpotato cultivating households had a reduced probability to consume cassava compared with the control group. Likewise, cassava cultivation household had a reduced probability of sweetpotato consumption. These results, in terms of significance and sign, suggest that confounding factors may be at play and that the multivariate probit results presented above are likely to be biased.

Next, PSM results for all three applied algorithms (nearest neighbor, radius and kernel) reveal an insignificant coefficient of planting sweetpotato as a disaster response for sweetpotato growing households. This is in contrast to the multivariate probit results finding a significant negative effect. Whereas the remaining coefficients for both sweetpotato and cassava groups enter insignificantly using the nearest neighbor algorithm, this changes when using radius and kernel PSM algorithms. Those results are in line with the multivariate probit estimations. The differences between the three PSM algorithms results may be explained by the number of treated and matched control households which are considerably larger for radius and kernel algorithms.

6. Discussion

Our findings highlight that cassava and sweetpotato, through their dual characteristics of (a) being underground crops and (b) having shorter growing cycles than other Asian staples, contribute to build the resilience of households in the context of a typhoon, allowing them to be better prepared and to bounce back faster and better. This is achieved through two distinct but complementary impact pathways. First, cassava and sweetpotato's resistance (being underground crops) means that households can still largely harvest undamaged food crops for own consumption, sale, or informal exchange after being hit by a typhoon, which is in line with other studies [57–59]. Second, their short cycle allows households who plant them after the typhoon to quickly access food, thus reducing their exposure to food insecurity. Additional crop characteristics, such as less intensive management and little input requirements [46], were not considered in this study but could also have been important in the aftermath of a typhoon as these allow households to divert (freed-up) resources (e.g., labor saved from intensive farm management and money saved on inputs) onto the household recovery process. Also, the drought tolerance of RTCs [47,52] and the ability of piecemeal harvesting [49–51] are often overlooked yet powerful traits in the wake of climatic shocks and change.

Regarding crop resistance, our findings suggest that growing RTCs before typhoon Ompong contributed to the resilience capacity of households. RTCs (i.e., cassava, sweetpotato, taro, and yam) were more resistant to the super-typhoon Ompong because these could better withstand the impacts compared to major aboveground crops (i.e., rice, maize and banana) [64]. Our data shows that almost all respondents who cultivated the latter crops experienced important crop losses. In contrast, for most RTCs, only 14–19% of households reported losses. Yam farmers reported losses of some 26% which is slightly more than for the other RTCs. This was likely due to the inability of yam to withstand an extensive period of waterlogging. Furthermore, the extent of crop losses for all aboveground crops were significantly higher compared to RTCs. Here the mentioned distinct characteristics of RTCs played a major role. As they grow underground, RTCs were protected from the impact of strong winds and heavy rainfalls [57–59]. However, the relatively large standard deviations found for proportion of crop lost across all crops studied also suggest that typhoon effects were not homogeneous within our study region and micro-conditions and location-specific characteristics were likely to be at play. More research is warranted regarding the impact of those characteristics and specific climatic shocks on various crops.

The results further reveal that various strategies were deployed by the households and contributed to build their resilience in the aftermath of the typhoon. This is in line with other studies which observed that the different strategies adopted, in anticipation of or in response to, adverse events are often more important in influencing the final outcome than the severity of the initial event [28,35]. Among the most frequently adopted coping strategies in our sample were the use of savings, and relying on neighbors or friends for assistance. In particular, our findings suggest that households who grew sweetpotato before the typhoon, did not rely on savings and support from neighbors or friends as much as households who had not grown sweetpotato. Possibly, much of the undamaged sweetpotato was used for own consumption, reducing the household's need to mobilize own savings and/or ask neighbors for food. In addition, undamaged harvested sweetpotato might have been sold to local markets to generate cash income or were exchanged for other desired consumables. This is an important finding as it underlines the importance of sweetpotato for household resilience by reducing the need to apply other, more detrimental, responses, such as selling household assets, taking out loans, migrating, reducing food consumption, or reducing on-farm labor to help rebuild the damaged house [15,16,76]. An alternative explanation for the lower frequency of adoption of more detrimental coping strategies may be the fact that, despite the severity of the typhoon, household food insecurity has not been reported to be severe in the study area. Households indeed reported that food insecurity was generally not a problem in the aftermath of the typhoon. Some staples, such as rice, were still partially available because a substantial amount was harvested and stored prior to the typhoon.

In the absence of severe food insecurity, our results suggest that sweetpotato and cassava influenced the type of responses and contributed to post-typhoon recovery. In particular, we found that households who grew sweetpotato and cassava before Ompong also consumed more of these crops in the aftermath of the typhoon. In itself, this finding is not surprising because resource-poor farming households usually eat what they grow, especially in times of limited market access. However, the relevance of sweetpotato and cassava is underlined here by the fact that other households who did not grow these crops prior Ompong, planted them in the first four weeks after the typhoon hit. Both consumption and planting of RTCs thus emerge as coping strategies deployed by households in the aftermath of a climatic shock, likely for ensuring short-term food security and longer-term recovery. While this corroborates recent findings [56,61–63], it is important to note that the focus of this study was on the contribution of RTCs to enhance resilience capacity and their influence on the responses put in place, rather than on assessing how these translate at resilience outcome levels. Therefore, we were unable to directly test these assumptions with the data at hand.

Surprisingly, we found that typhoon duration played a minor role in explaining households' coping strategy choices, as suggested otherwise by other studies [e.g., 11]. The number of days households were exposed to heavy rainfall and strong winds only increased the probability to ask neighbors for assistance but not the frequency of the other responses. One explanation could be that location-specific conditions were at play. For some households who were hit the hardest, most of the damages were incurred in the first 1–2 days of impact, for others who were not directly hit, typhoon duration for several days may have been more important in determining damages brought about, for example, by flooding and thus triggering households to adopt coping strategies.

Reduced mobility appeared to be a more important typhoon-related factor. But in addition to negative implications related to limited market access [12–14], we found a significant positive effect on the probability that households consumed sweetpotato and cassava. Apparently, longer periods of limited access to markets for buying and selling food, resulted in an increase of home consumption of RTCs. Combining these findings with the fact that RTCs are more resistant to extreme weather events, allowed farmers who cultivated these crops before Ompong to be better prepared for the shock.

We found that, on average, better-off households grew more often sweetpotato and cassava, and were thus better prepared for disaster. These households could either sell or exchange undamaged produce or use them for home consumption. All those households with RTCs in the field prior to Ompong consumed what they had grown, irrespective of wealth status. However, the findings also suggest that wealthier households who were not as well-prepared (i.e., high income but without RTCs before Ompong), also consumed more sweetpotato and cassava in the aftermath of the typhoon. These households possibly had more cash money or goods to exchange to acquire sweetpotato or cassava than resource-poor households.

In contrast, resource-poor household responded to the disaster by planting sweetpotato and cassava after the typhoon struck. As resource-poor households less frequently had sweetpotato and cassava in the field when Ompong hit and they could only harvest the sweetpotato and cassava planted after four (for sweetpotato) to nine months (for cassava), they may have ended up being more food insecure for those months. This is further supported by our results that show that resource-poor households were more likely to use savings as a coping strategy.

The finding that resource-poor households were more likely to plant sweetpotato and cassava after an extreme weather event nuances the earlier finding that household who cultivated sweetpotato or cassava before Ompong were relatively wealthier. Because sweetpotato and cassava are crops which require relatively few inputs and less intense management, planting these crops on marginal lands may be preferred by resource-poor households. This has been found in various other Asian countries [83].

Overall, rice still remains the mainstay of agricultural production in our study area and RTCs are secondary crops and only cultivated if resources allowed so. That would explain why wealthier households cultivated RTCs significantly more prior to Ompong. Anecdotal observations confirmed this, as several respondents reported that RTCs were mainly used as snacks, and during field visits the study team would frequently receive tea with boiled sweetpotato. In contrast, planting of RTCs as an early-response crop in the aftermath of the typhoon may have been more of a conscious decision made by particularly resource-poor households.

This research has some limitations. First, data collection was cross-sectional and restricted to areas which were affected by the typhoon. This means that we were unable to draw on before-after typhoon scenarios and did not have a proper counterfactual group to compare households with typhoon exposure to households without. In theory, these limitations could be partially overcome or reduced through the use of panel data or randomized control trials (RCTs). However, besides being time and resource intensive -and ethically disputable - the use of RCTs is further constrained in the case of extreme weather-events by the largely unpredictable nature of these events in terms of timing, location of impact, and track (making the planning and implementation of these RCTs almost impossible). In those conditions, using matching techniques to build a pseudo-counterfactual and deal with selection issues was our second best-option [84].

Second, our data may partly be subject to recall bias since we conducted the surveys some five months after the typhoon. An earlier data collection, however, could have resulted in a different – such as emotional or concentration – bias because households were likely to be (emotionally and physically) occupied in post-disaster activities [85]. Third, data constraints did not allow us to investigate in-depth the gender dimension of the processes studied here, which would have been informative as many RTCs are often considered 'female crops' and home gardens controlled by women [86]. Future research is warranted to analyze the role women have in the aftermath of climatic shocks and how power dimensions possibly change, especially in the light of promoting RTCs as more profitable cash crops, which is often a male dominated domain.

Finally, as previously mentioned, it should be noted that because we did not collect information about other food sources, it was not possible to analyze the extent to which RTCs contributed to long-term food security, in terms of intake, in relation to those other crops. For instance, almost every respondent reported that rice was the main food crop consumed after Ompong, most of which stored from the previous season or in preparation to the typhoon. Analyzing food intake from different food sources, breaking down the availability of calories and micronutrients, in the aftermath of climatic shocks could be an important avenue of future research.

7. Conclusions

In this study, we provided evidence of the contribution of cassava and sweetpotato to households' resilience capacity and the influence they have on the coping strategies households apply in the aftermath of a climatic shock. In using cross-sectional data for 423 rural households who were all affected by super-typhoon Ompong in 2018 in the Philippines, we showed that several roots and tuber crops (RTCs) are strategic choices in the face of a climatic shock due to their biological characteristics. First, growing underground give RTCs a comparative advantage over crops that grow aboveground, many of which are staples in our study region and in South-East Asia in general, such as rice and maize. We found that crops that grow underground are inherently more resistant to heavy rainfall and strong winds compared to aboveground crops. It can be concluded that growing cassava and sweetpotato contributes considerably to households' resilience capacity. This provides farmers with a specific crop choice which is in contrast to other studies that stress the general importance of agricultural crop diversification for resilience [e.g., 29,30]. Second, cassava and in particular sweetpotato are short-cycle crops that require little inputs and agronomic knowledge. These characteristics are relevant in the aftermath of a climatic shock when farmers decide which coping strategies to deploy. Adding, for instance, sweetpotato to the portfolio of responses not only contributes to food security but also eases the pressure to apply other, more negative, responses, such as asking for assistance or using savings, as our findings suggest. Overall, sweetpotato, cassava, and likely other root and tuber crops with similar traits contribute considerably to household resilience capacity and possibly to food security during climatic shocks (for potato in India see Pradel et al. [87]).

These findings are relevant for designing effective agriculture-nutrition interventions which aim at increasing households' resilience capacity and effective coping strategies during climatic shocks. In doing so, policy-makers, donors, but also NGOs need to be aware that many RTCs, but especially sweetpotato and cassava, remain minor crops in the Philippines, often cultivated in marginal lands. This implies that positive impacts are limited and their potential still untapped. In the longer-run, policy-makers are advised to stimulate farmers to reserve parts of the main plots for RTC cultivation to reach larger positive impacts. Accordingly, we recommend exploring opportunities for product development and functional upgrading of RTC value chains and to start changing the image of these crops which are often considered minor subsistence crops for "the poor". This would require investments to create markets, develop seed systems, engage private sector, and promote enterprise development [88].

The study results may also be valid in other countries around the world which are plagued by recurring extreme weather events, such as super-typhoons, flooding, or drought, and households may benefit from wider adoption of root and tuber crops. The importance of RTCs as a post-disaster and early-response crop, given their various 'climate-smart' characteristics, to ensure food and nutrition security has likely huge potential also at times of other sudden market and value-chain disruptions, such as the ones caused by the measures to stop or slow the spread of pandemics, as the world is currently facing.

Data availability

Datasets and questionnaire used in this study are publicly available in Dataverse (https://doi.org/10.21223/FP47JO).

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. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2021.102392.

Appendix

Table 1A
Correlation matrix of major crops

	Rice	Banana	Sweetpotato	Maize	Taro	Cassava	Yam
Rice	1						
Banana	−0.14***	1					
Sweetpotato	0.19***	−0.03	1				
Maize	−0.24***	0.13***	−0.15**	1			
Taro	−0.14***	0.04	−0.27***	0.03	1		
Cassava	−0.13***	0.06	−0.18***	0.03	−0.01	1	
Yam	−0.12**	0.08	−0.03	0.02	0.13***	0.05	1

Notes: ** significance at the $P < 0.05$ level; *** significance at the $P < 0.01$ level.

Table 2A
Household assets and damages by Ompong

Variables	Ownership (mean)	Damaged (%)
Cellphone	0.830	0.6
Pigs/Native pigs	0.643	1.5
TV (with satellites)	0.601	9.8
Sprayer	0.579	2.0
Electric fan	0.461	1.5
LPG/kerosene stove	0.402	0.6
Carabao	0.383	1.2
Motorbike	0.296	1.6
Washing machine	0.191	3.7
Refrigerator	0.191	1.2
Radio	0.165	0.0
Kuliglig (improvised vehicle tractor)	0.144	3.3
Plough	0.118	2.0
TV (w/o satellites)	0.111	4.3
Bicycle	0.073	0.0
Computer/laptop	0.064	0.0
Cow	0.052	4.5
Tablet	0.047	0.0
Car/jeep/truck	0.043	5.6
Irrigation/water pump	0.041	5.9
Thresher	0.038	6.3
Tricycle	0.035	6.8
Weeder	0.031	0.0
Cart/trailer/wheel barrow	0.024	0.0
Hand tractor	0.012	20.0
Combined harvester	0.000	0.0
Pedicab	0.000	0.0
Aircon	0.000	0.0
Electricity	0.967	71.9
Electricity disruption (#days)	17.76	

Table 3A
Multivariate Regression Results with Income 2017 interaction.

	Consumption Sweetpotato	Consumption Cassava	Planting Sweetpotato	Planting Cassava	Use Savings	Neighbor assistance
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Grow sweetpotato	0.285 (0.756)	0.034 (0.407)	−0.704 (0.334)	−0.427 (0.413)	0.798 (0.336)	0.193 (0.478)
Grow cassava	0.205 (0.746)	−0.141 (0.184)	−0.671 (0.325)	−0.442 (0.434)	0.716 (0.408)	0.142 (0.636)
HH size	−0.015 (0.014)	−0.007 (0.009)	−0.014 (0.012)	−0.007 (0.012)	0.002 (0.009)	−0.017 (0.011)
Male	0.185 (0.101)	−0.089 (0.118)	−0.005 (0.122)	−0.211* (0.112)	0.100 (0.072)	0.074 (0.094)
Age	0.003 (0.002)	0.000 (0.001)	−0.002 (0.002)	−0.000 (0.002)	−0.001 (0.002)	−0.001 (0.002)
Married	−0.108 (0.087)	0.070 (0.042)	0.049 (0.084)	0.197* (0.078)	−0.075 (0.072)	0.006 (0.068)
Education (years)	0.001 (0.008)	−0.005 (0.004)	−0.001 (0.006)	0.004 (0.006)	−0.004 (0.005)	−0.006 (0.006)
Income 2017 (log)	0.131*** (0.039)	0.044** (0.022)	−0.132*** (0.039)	−0.091** (0.037)	−0.007 (0.021)	−0.002 (0.031)
Income 2017 X grow SP	0.045 (0.069)	0.005 (0.034)	0.051 (0.054)	0.036 (0.048)	−0.083* (0.034)	−0.023 (0.041)
Income 2017 X grow C	−0.019 (0.063)	0.050 (0.034)	0.063 (0.061)	0.046 (0.061)	−0.061 (0.047)	−0.021 (0.053)
Area (log)	−0.026 (0.023)	0.002 (0.017)	0.038* (0.025)	0.023 (0.023)	0.003 (0.021)	0.002 (0.022)
Wind/rain (days)			−0.019 (0.211)	−0.008 (0.021)	−0.006 (0.017)	0.033* (0.018)
Reduced mobility (days)	0.028** (0.011)	0.017*** (0.005)				
Pseudo R-squared	0.48	0.33	0.11	0.04	0.05	0.02
N			423			
Log likelihood			−1202.47			
Wald chi2 (84)			451.56			
Prob > chi2			0.00			

Notes: marginal effects; figures in parenthesis are robust standard errors; results for variables 'SP & C' and 'Income 2017 X grow SP & C' not shown.
Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{51} = \rho_{61} = \rho_{32} = \rho_{42} = \rho_{52} = \rho_{62} = \rho_{43} = \rho_{53} = \rho_{63} = \rho_{54} = \rho_{64} = \rho_{65} = 0$, $chi^2_{(15)} = 158.313$, p-value = 0.000.
***significant at the 1% level; **significant at the 5% level, *significant at the 10% level.

Table 4A
Additional propensity score matching results for SP-only category using radius (0.1) and kernel matching techniques

Matching technique	Outcome variable	ATT	*t*-value[a]	Number of treated	Number of control
Radius	Consumption of SP	0.657*** (0.042)	15.598	134	280
	Consumption of C	−0.137*** (0.042)	−3.281	134	280
	Planting SP	−0.249*** (0.053)	−4.690	134	280
	Planting C	−0.106** (0.052)	−2.025	134	280
	Savings	−0.101** (0.042)	−2.383	134	280
	Neighbor assistance	−0.105** (0.045)	−2.308	134	280
Kernel	Consumption of SP	0.625*** (0.042)	15.010	136	280
	Consumption of C	−0.204*** (0.048)	−4.228	136	280
	Planting SP	−0.183*** (0.057)	−3.231	136	280
	Planting C	−0.027 (0.055)	−0.486	136	280
	Savings	−0.057 (0.044)	−1.279	136	280
	Neighbor assistance	−0.090* (0.048)	−1.889	136	280

Notes: Bootstrapped standard errors in parentheses. Bootstrapping done with 1000 replications. [a] 1% level one tailed test: *t*-critical value = 2.326; 5% level one tailed test: *t*-critical value = 1.645; 10% level one tailed test: *t*-critical value = 1.282; * significance at the 10%-level; ** significance at the 5%-level; *** significance at the 1%-level. ATT: average treatment effect of the treated. SP: sweetpotato; C: cassava.

Table 5A
Additional propensity score matching results for C-only category using radius (0.1) and kernel matching techniques

Matching technique	Outcome variable	ATT	T-value	Number of treated	Number of control
Radius	Consumption of SP	−0.316*** (0.044)	−7.123	89	310
	Consumption of C	0.368*** (0.058)	6.329	89	310
	Planting SP	−0.003 (0.059)	−0.056	89	310
	Planting C	0.016 (0.062)	0.254	89	310
	Savings	0.043 (0.055)	0.782	89	310
	Neighbor assistance	−0.031 (0.052)	−0.598	89	310
Kernel	Consumption of SP	−0.312*** (0.044)	−7.098	89	310
	Consumption of C	0.371*** (0.058)	6.425	89	310
	Planting SP	−0.006 (0.059)	−0.093	89	310
	Planting C	0.015 (0.060)	0.249	89	310
	Savings	0.041 (0.052)	0.788	89	310
	Neighbor assistance	−0.034 (0.051)	−0.666	89	310

Notes: Bootstrapped standard errors in parentheses. Bootstrapping done with 1000 replications. [a] 1% level one tailed test: *t*-critical value = 2.326; 5% level one tailed test: *t*-critical value = 1.645; 10% level one tailed test: *t*-critical value = 1.282; *** significance at the 1%-level. ATT: average treatment effect of the treated. SP: sweetpotato; C: cassava.

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