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Research

Recovery and adaptation after the 2015 Nepal earthquakes: a smallholder household perspective

Kathleen Epstein[1], Jessica DiCarlo[2], Robin Marsh[3], Bikash Adhikari[4], Dinesh Paudel[5], Isha Ray[6] and Inger E. Måren[7]

ABSTRACT. Communities reliant on subsistence and small-scale production are typically more vulnerable than others to disasters such as earthquakes. We study the earthquakes that struck Nepal in the spring of 2015 to investigate their impacts on smallholder communities and the diverse trajectories of recovery at the household and community levels. We focus on the first year following the earthquakes because this is when households were still devastated, yet beginning to recover and adapt. Through survey questionnaires, focus group discussions, open-ended interviews, and observations at public meetings we analyze physical impacts to farming systems and cropping cycles. We investigate respondent reports of loss and recovery through a new social-ecological recovery assessment instrument and find that diversification of livelihoods and access to common resources, alongside robust community institutions, were critical components of coping and recovery. There was widespread damage to subsistence farming infrastructure, which potentially accelerated ongoing transitions to cash crop adoption. We also find that perceptions of recovery varied widely among and within the typical predictors of recovery, such as caste and farm size, in sometimes unexpected ways. Although postdisaster recovery has material and psychosocial dimensions, our work shows that these may not change in the same direction.

Key Words: *assessment; community resources; coping strategies; disaster; farming systems; Himalaya*

INTRODUCTION

In spring of 2015, Nepal was struck by a string of massive earthquakes and a series of aftershocks, causing approximately 9000 deaths, 23,000 injuries, and the destruction of 600,000 family homes (NPC 2015). Damages amounted to over one-third of the national Gross Domestic Product (GDP). Disasters affect different communities in different ways (White 1945), and rural subsistence-based populations are typically among the most vulnerable (Wisner et al. 2004, Cutter et al. 2006). In this case, mid-hills, smallholder farming communities near the epicenters in Nepal were devastated.

Reducing vulnerability to natural disasters at multiple scales is vital to meeting the broader goals of poverty reduction and sustainable development. The 2030 prediction that "325 million people [will be] trapped in poverty and exposed to the full range of natural hazards and climate extremes" (UNISDR 2015:2) may explain why so many donors have prioritized risk reduction and resilience building in their strategic planning[1]. This focus is not new, however, and can be traced to earlier work recognizing the twin components of vulnerability and asset-building for achieving food security and sustainable rural livelihoods (e.g., Chambers and Conway 1992, Scoones 2009, Ashley and Carney 2017).

Given the pervasiveness of disasters, there is widespread interest in understanding their impacts on agricultural systems broadly, as well as in the capacity of smallholder households to recover and adapt (Scheffer et al. 2001, Folke et al. 2004, Adger et al. 2005, Marín et al. 2014). Recovery in this context refers to a process of "bouncing back" to, or close to, a predisaster state (Klein et al. 2003, Cutter et al. 2008*a*), whereas adaptation refers to the potential for household, community, or region-wide systems to be transformed into (potentially) stable new states (Folke 2006, Cutter et al. 2008*b*). We assess diverse aspects of the smallholder farming system to understand the impacts of the 2015 earthquakes, the nature of recovery, and potential for adaptation.

In Nepal, subsistence agriculture accounts for more than two-thirds of rural livelihoods and contributes more than 35% of the national GDP (Ghale 2008, Adhikari 2011). Smallholder farm communities function as tightly coupled human-natural systems where on-farm activities are closely linked with off-farm resources and ecosystem services (Måren et al. 2014). Today, Nepali agricultural systems throughout the mid-hills are transitioning from subsistence and self-reliance to greater market insertion; these changes are being driven by out-migration, economic development, agricultural modernization, and climate change (Pandit et al. 2014, Tulachan 2001). Superimposed on these transitions are environmental shocks and disasters such as landslides, flooding, and earthquakes; all of these can radically alter rural agricultural landscapes and catalyze rapid shifts in farming practices toward broader transformations (Folke et al. 2005).

This study was conducted in Dolakha district, Nepal, in the year following the 2015 earthquakes, a period of recovery and adaptation for affected households and communities. We explored the factors that make smallholder households more or less able to recover from disasters. To understand the impacts and trajectories of recovery after the 2015 earthquakes, we asked the following: (1) What were the specific impacts of the earthquakes on smallholder households? (2) How did smallholder households recover from, and adapt to, these impacts in the immediate aftermath, and over a year? (3) What factors may explain variations in perceptions of loss and recovery among these households? Our work is exploratory and aims to generate, rather than test, hypotheses on postdisaster recovery and adaptation against the backdrop of ongoing transformations.

[1]Department of Earth Sciences, Montana State University, [2]Department of Geography, University of Colorado Boulder, [3]Institute for the Study of Societal Issues, University of California, Berkeley, [4]Institute of Forestry, Tribhuvan University, Pokhara, Nepal, [5]Department of Sustainable Development, Appalachian State University, [6]Energy and Resources Group & Berkeley Water Center, University of California, Berkeley, [7]Department of Biological Sciences, University of Bergen, Norway

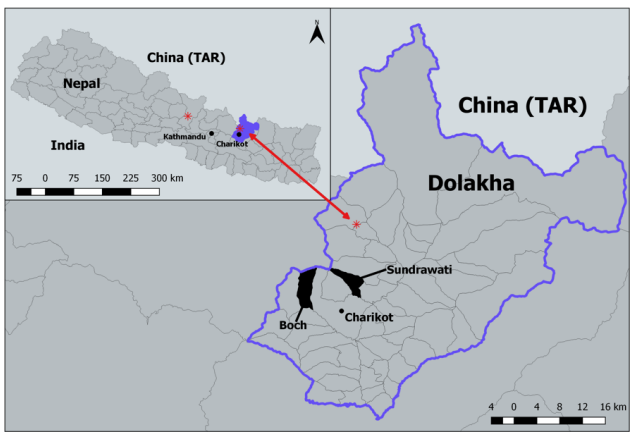
We addressed our research questions by analyzing postdisaster impacts and adaptation within ongoing agricultural change in mid-hills smallholder communities. Through our mixed methods approach, we sought to show the differentiated damages that the 2015 earthquakes imposed on subsistence farming and mixed subsistence-plus-cash crop systems, and discuss the implications of these differences for farming households. We developed a new self-assessment instrument that captures multiple indicators of recovery to better understand community and household well-being. Recovery is an important component of well-being in the aftermath of a disaster, where well-being, following Sen (1985), broadly describes life satisfaction in its material as well as psychosocial dimensions. Accordingly, the self-assessment instrument reveals how households "see" their postearthquake recoveries and includes subjective indicators as well as material indicators such as crop production losses and housing structures repaired. Our analysis focused on the experiences of each and the "fit" between the two. Our work thus acknowledges that although tangible measures of recovery are absolutely critical, psychosocial perceptions, which are often overlooked among smallholder farmers, are also central to well-being.

METHODS

Study sites

We conducted our research in Dolakha district, Nepal (27°40'0"N 86°2'0"E), population 186,557 (NPC 2015), a mountainous region that was hit hard by the 2015 earthquakes (Fig. 1). The economy is predominantly smallholder agricultural; subsistence farmers grow maize, wheat, rice, and millet on terraced plots. Many farmers maintain livestock including oxen, cows, goats, and chickens, which graze on public or commonly held land. Most maintain small kitchen gardens with fruits, vegetables, and spices. Adjacent forestlands, managed by community forest user groups, provide firewood, timber, fodder, and edible and medicinal plants. Many farmers have adopted cash crops on a part of their lands; the most common are kiwi, vegetables, potato, and cardamom.

Fig. 1. Map of study sites in the Dolakha District of Nepal. Epicenters of the two massive earthquakes 25 April, magnitude 7.8 NW of Kathmandu in Gorkha District and 12 May, magnitude 7.3 NE of Kathmandu in Dolakha District are denoted by *.



We collected data in the villages of Sundrawati and Boch in Dolakha. These villages are representative of the socio-demographic characteristics, caste range, and agricultural practices of mid-hills smallholder-dominated Nepal (Central Bureau of Statistics 2013; Appendix 1). The mean landholding size was 0.56 hectare in Boch and 0.47 in Sundrawati. We restricted our study to farms between 1500 and 2200 meters above sea level for biophysical and agricultural consistency.

Data collection

To understand the physical and psychological impacts of the earthquakes on our study communities, we conducted 24 open-ended interviews with community leaders, farmers, academics, and aid workers, and held five focus group discussions with a range of participants (Appendix 2). We also participated in several public events, including community forestry group meetings, village development committee meetings, and festivals. The interviews focused on pre- and postearthquake experiences at household and individual levels with respect to farming, off-farm livelihoods, coping strategies, adaptation strategies, and access to housing, public services, forest ecosystem services, and relief interventions. Focus group discussions identified community-level experiences and acted as a crosscheck on interview results. All interviews were conducted in Nepali and subsequently coded for emergent themes. In addition, we conducted a structured survey to assess earthquake damages among 79 farm households (31 female and 48 male respondents), selected via a random sample, stratified by farm elevation, and based on village development committee census data (2011). The survey (Appendix 3) documented impacts to housing and farm structures, crop production, livestock, water, and seed stocks, as well as community-based institutions and resources.

Recovery assessment

We developed a comprehensive recovery assessment instrument comprising indicators based on the disaster risk management literature (Cutter et al. 2008*a*) and social-ecological metrics (Bergamini et al. 2013, O'Connell et al. 2015, Altieri et al. 2015). For disaster-specific scenarios, Cutter et al.'s (2008*a*) "disaster resilience of place" (DROP) framework unites ecological and social factors with features of the built environment to assess community resilience following natural hazards. Buck and Bailey's (2014) social-ecological indicators develop a landscape framework to elucidate connections among livelihood, agroecosystem, institutional, and ecosystem resilience(s). We built on DROP and Buck and Bailey's work to identify three categories of social-ecological system assessment: farming system and livelihoods, community resources, and household resources. Within these categories, we created a unique set of 10 multiscale indicators and operationalize them into 29 metrics specifically tailored to smallholder farming communities (Table 1).

Each participant compared the status of each indicator across three time periods, (i) immediately before the earthquakes, as a baseline measure; (ii) six months after the earthquakes; and (iii) one year after. All answers for the indicator-based scoring system were self-reported perceptions, coded as -1 if status declined, 0 if it stayed the same, and 1 if it improved. Our purpose was to capture the perceived direction of change and concomitant household perceptions of recovery, alongside more objectively measurable dimensions of material recovery.

Table 1. List of categories, indicators, and metrics within the "recovery assessment" used to track resilience following natural disasters for small-farm households (n = 79). Indicators are derived from the literature and adapted to the Nepali context. We recorded respondents' self-assessment of whether they were doing better, worse, or about the same on each of these metrics at zero to six months after the earthquakes and one year after the earthquakes, compared to before the earthquakes.

Category	Indicator	Metrics (self-reported)
Farming Systems and Livelihoods	Farm Inputs and Production	Food crop productivity
		Cash crop productivity
		Overall crop quality
		Diversity of crops produced
		Seed storage system
		Contributions of off-farm income
	Water and Soil	Erosion on farm
		Access to irrigation water
		Irrigation system
	Forest and Pasture Lands	Access to forest resources
		Access to grazing lands
	Livestock	Status of livestock
		Farm structures/animal sheds
		Use of livestock
Community	Community Institutions	Access to local schools
		Access to local health facilities
		Participation in community groups
	Social and Religious	Participation in festivals
		Ability to engage with social networks
	Self-Reliance	Capacity to help with rebuilding
		Reliance on NGO aid
		Reliance on local institutions
Household	Housing	Access to safe housing
		Access to comfortable housing
	Food Security	Ability of farm to provide food
		Frequency of not having enough to eat
	Health and Sanitation	Access to drinking water
		Access to clean toilets
		Access to water for hygiene/cleanliness
		General physical health

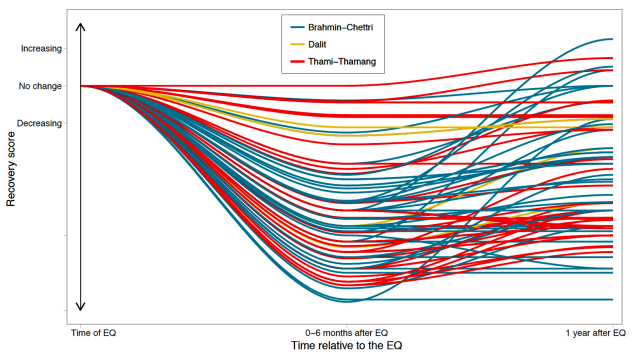
We used these scores as dependent variables to generate descriptive statistics, via simple linear regressions and ANOVA, to show how perceived household-level economic recovery, as well as recovery of general well-being indicators were (or were not) correlated with potential predictors of recovery. The main predictors suggested by the literature are caste, land size, crop diversification, off-farm income (e.g. employment or remittances), and access to community-based common resources (such as forests and grazing land). Finally, we created two visual schematics (Figs. 2 and 3) to show the range of reported recovery pathways to the predisaster "normal" (following Holling 1973), by aggregating individual responses for each time period, for each of the three social-ecological system categories and their respective indicators (Table 1).

RESULTS AND DISCUSSION

Impacts and adaptation strategies

Overall, key inputs to subsistence agriculture, including water, seeds, livestock, and land, suffered the most damage. The earthquakes and associated aftershocks and landslides struck during the maize and millet harvest season, and just as rice paddies were being prepared for planting. Destruction to housing and farm infrastructure was similar across the two communities; reported damage to housing, seed stocks, livestock, and irrigation

Fig. 2. Plot of recovery assessment score trajectories for the four farming system and livelihood indicators (farm inputs and production, livestock, water and soil, and forest and pasture lands; Table 1). Each curve represents an individual respondent; n = 79. The direction and magnitude of the trajectory along the X-axis, "0–6 Months after EQ" and "1 Year after EQ," represent an average of responses across the selected indicators. Colors represent respondent's reported caste group: Brahmin and Chettri, Thami and Thamang, and Dalit.



canals was 100%, 86%, 46% and 38%, respectively (Table 2). In the immediate aftermath of the earthquake, families assisted one another in recovering victims, food, and possessions from collapsed structures. Community-based organizations such as forest user groups and mothers' groups were among the first local responders, distributing timber, firewood, tin, and cash to households on a needs basis.

Fig. 3. Spider diagram of earthquake (EQ) impacts to all 10 adaptation and recovery assessment indicators (Table 1). Scores for individual metrics are averaged across total respondents (n = 79). The outer edge represents the self-assessed pre-earthquake baseline. The closer to the center an indicator falls, the more an indicator declined relative to the pre-earthquake baseline; the closer it is to the outer edge, the more an indicator recovered.

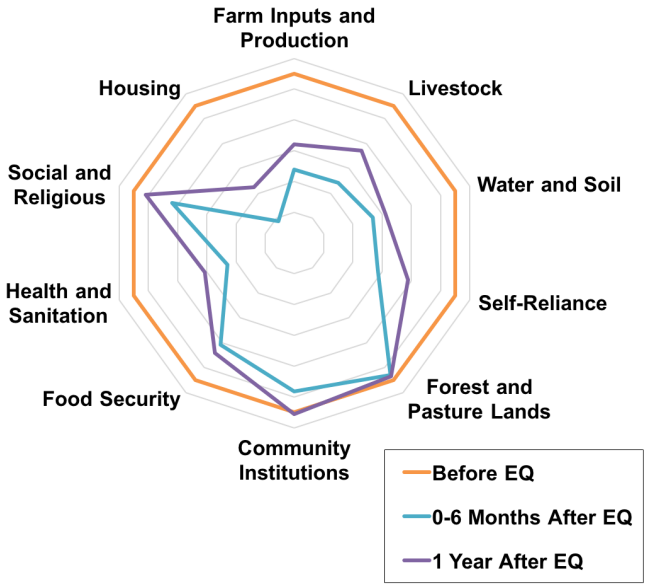


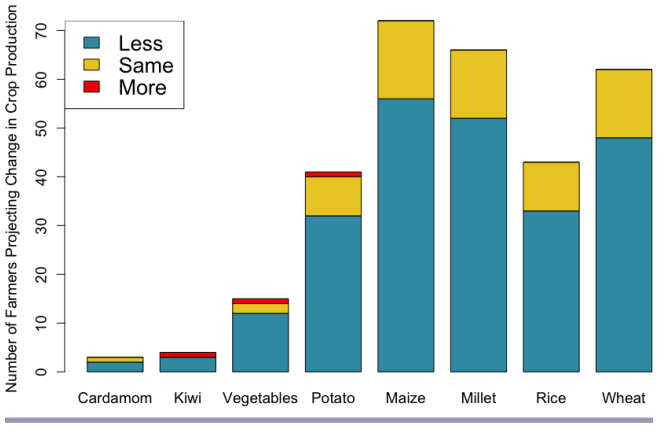
Table 2. Summary of earthquake impacts to farming systems from survey results in both study communities (n = 79).

Farm system structures and inputs	Sundrawati	Boch	Pooled
Housing structures	100.0%	100.0%	100.0%
Seed stocks	84.6%	87.5%	86.0%
Irrigation canals	41.0%	35.0%	38.0%
Livestock loss	56.4%	35.0%	45.7%

Damage to fields and terraces impeded subsequent grain cultivation. For wheat, maize, and millet, terraces are essential for good drainage, and for rice, terraces are essential to hold water. Small canal systems were severely damaged, reducing reliable water supply for rice production. Seed stocks of maize, millet, wheat and rice were irretrievable from collapsed houses; lower harvests, by 50% on average, forced people to eat into seeds kept aside for planting. In the words of the district agriculture development officer: "farming in Dolakha has been set back 10 years."

In the monsoon farming season one year following the earthquake, several farmers started to change their planting regimes. The majority of farmers in both study sites reported large decreases in total acreage planted because of damaged terraces and canals, scarcity and high cost of labor, loss of draught animals, and reduced seed stocks. Projected crop output from the 2016 growing season was consequently well below pre-earthquake levels for both communities, for both cash and subsistence crops (Fig. 4). Just three respondents planted additional acreage after the earthquake; these farmers, all higher caste Brahmin or Chettri, planted cardamom, kiwi, potato, and green vegetables for sale. Our interviews showed that many farmers who experienced severe damage to their subsistence farming systems planned to focus more on labor-saving income-generating cash crops in the future (Table 3).

Fig. 4. Bar chart of changes in crop planting for the 2016 harvest year based on farmer responses. Respondents were questioned on their 2016 planting regimes compared with before the earthquakes. The X-axis shows common crops and the Y-axis shows the number of farmers who planted "less," "the same," or "more" of each crop for the 2016 planting cycle (n = 79).



The combined impacts of the disaster and the nature of the aid that followed brought about differentiated adaptation strategies that appear to have hastened ongoing agriculture transitions. For some, it brought greater integration into the labor market and cash economy, for others a contraction of subsistence production and an uncertain future. Our interviews reveal that physical impacts from the earthquakes increased the incentive to integrate more land- and labor-saving cash crops into smallholder systems. Large holes and cracks in the fields made rice or wheat cultivation more difficult or in some cases impossible, and water supplies for cereal crops became unreliable. Cardamom, kiwi, and potatoes remained viable; these crops require purchased inputs, but can be grown on damaged terraces and need light watering compared to grains. Recovery and development interventions further incentivized these transitions through seed donations of cash crops, loans for projects such as greenhouses, and technical training sessions on market-oriented agriculture.

The need for cash during the first year rose sharply. As farm land dedicated to food-grains fell, some families drew on commercial crop sales and off-farm income and remittances, and others

sought wage opportunities locally. Selling draught animals and other livestock was necessary for some households, in part for cash and in part in response to the reduction in planted area. Access to farm labor fell as priority was given to house reconstruction and relief efforts as government and donor aid came in; the labor that remained for agricultural work became expensive. With the increase of wage labor rates (by up to 50%) for postearthquake reconstruction, the poorest households reported increased wage earnings.

Table 3. Individual representative quotations from multiple respondents describing earthquake impacts and responses to farming systems; generated from semistructured and open-ended interviews conducted May–July 2016 in Dolakha District, Nepal.

Earthquake Impact	Earthquake Evidence
Labor	Without an ox it's difficult to plow my fields and plant maize.
	I sold my ox after the earthquake because we needed to sleep in the animal shed and there was no room for animals.
	All of my goats were injured by the earthquake damage. We were forced to sell them or eat them as meat.
	My husband went to get work in Kathmandu to help pay for our new house. I'm going to start growing kiwis because they take less work.
	I had to leave my *khet* [irrigated field] fallow. It was too much work to plant rice. Now I grow potatoes instead.
	I used to earn 500 rupees [US$5] a day to work in the farmlands. Now I make almost twice that (Dalit or low-caste, farmer).
Water	Without water to irrigate my farmland, I need a new crop to plant. My neighbors say cardamom is a good option.
	The local springs I use on my farm were damaged after the earthquake. I want to plant trees near the spring to protect the water source. I can grow cardamom too.
	My irrigation canals were damaged. I have no time to maintain them.
Seeds	Local NGOs are giving away free vegetable seeds, so I started growing vegetables.
	All my maize and rice seeds were destroyed in the earthquake.
	The government has distributed vegetables, kiwi, and cardamom seeds so I started to grow cash crops.
Cash Income	I can get income quickly from cash crops compared with subsistence. I need cash to pay for my basic expenses, which have increased after the earthquake.
	I put up a greenhouse this year to grow and sell green vegetables. It's the easiest way to get money quickly.
Housing	The earthquake destroyed our house and we couldn't live there. Right after the earthquakes, our priority was finding shelter.

From a recovery perspective, livelihood diversification is a long-standing strategy of rural communities (Ellis 2000) and may enhance the capacity to manage risk (Barrett et al. 2001) and adapt to change (Marschke and Berkes 2006). At our earthquake-stricken sites in Nepal, the majority of respondents remained committed to maintaining some subsistence cropping. At the same time, observed shifts in planting regimes toward commercial crops, coupled with ongoing environmental impacts due to climate change, are likely to have system-wide ramifications. Other studies have argued, for example, that cash crop-dominated economies often require additional government programs and infrastructure investments that tend to reduce flexibility and increase vulnerability among smallholder communities (Feintrenie et al. 2010).

Self-assessed recovery in agricultural livelihoods

Our recovery assessment investigated whether households perceived components of their social-ecological system (such as crop production, or access to irrigation water) to be "improving," "staying the same," or "declining" after the earthquakes. Results from the 79 assessment responses show negative impacts across almost all respondents immediately after the earthquakes but substantial variation in the reported degree of recovery within one year (Fig. 2).

Regression and ANOVA analyses of indicators against commonly cited predictors of variation in recovery trajectories, such as livelihood diversity, crop diversity, land size, or caste, did not prove explanatory (Appendix 4). Our extensive interviews and focus group discussions revealed that recovery trajectories and sense of recovery were largely specific to household-level circumstances. All three caste groups show declines in perceived recovery a year out from the shock; the mean scores between the high-caste and the low-caste groups are almost the same, but the spread in recovery scores within the upper two castes (Brahmin-Chettri and Thami-Thamang) is wide (Fig. 2). For example, regarding adaptation and recovery in farming systems, one Dalit family reported little negative impact over six months or one year; the family's land was small (0.7 hectare) and had no irrigation, and the farming system, in effect, did not have much to lose or recover from. Their one-year self-assessed trajectory appears stable. A Brahmin family, whose indicators dipped sharply immediately after the earthquake, typically planted crops in both *khet* (irrigated field) and *bari* (unirrigated field). The family had much to lose initially, but a rebounded assessment score reflects that they were able to restore planting regimes to near-normal a year after the earthquakes. In contrast, another Brahmin family explained that their viable landholding had plummeted from 10 *ropani* (approximately 0.5 ha) to 4 *ropani*; this family judged themselves as not having recovered at all. Thus similarities or differences in assessment scores between households could embody very different trajectories and material positions, and within-group variation tended to overwhelm across-group variation.

The earthquake initially affected many of the respondents in similar ways. Yet self-assessed recovery trajectories of farming systems were highly differentiated, even among seemingly similar smallholder farmers. The results reveal three general patterns in our qualitative and survey data. First, cash needs for all rose sharply, but access to cash varied widely, including by caste, cultivation of cash crops, access to remittances, and receipt of aid. Relief and recovery measures may have increased access to cash and material goods (through donations of home and farming implements) for very poor farmers, compared to their pre-earthquake baseline. A few poorer families, for example, felt that their farming systems were about the same or even better a year after the earthquakes. Wage-dependent families benefited from the increased labor demand, and from cash and food aid (one such farmer noted: "now we can give our children rice"). Second,

households with somewhat larger and more diversified farms felt their losses acutely. This was reflected in sharp dips in their self-assessments. Many were unable in a year to recover to what they saw as a normal material (or social) state. Third, farmers with the quickest improvement trajectories (slope of perceived improvement from the time "0–6 Months after EQ" to "1 Year after EQ"; Fig. 2) had access to broad social networks, both within their villages, in Kathmandu, and in countries abroad, to aid in recovery.

Material estimations and assessments of resilience tend to dominate the postdisaster agricultural literature (Lin 2011, Marín et al. 2014, Castonguay et al. 2016, Seidl et al. 2016), though psychosocial metrics also offer important and nuanced measures of recovery. Although recovery is always a combination of physical and psychological well-being, our findings suggest that we cannot assume that these components will converge (see Carpenter et al. 2005, Cote and Nightingale 2012). It is possible for the most insecure households to feel recovered by experiencing some sense of improvement, at least temporarily, with increased access to aid or wage labor, while other, more asset-endowed and economically secure families remain well below their previous levels of perceived well-being. Future research could fruitfully explore the connections between material and psychosocial dimensions of recovery from natural disasters in smallholder farm communities.

Self-assessed recovery beyond livelihoods

The recovery assessment included, in addition to farming system and livelihood indicators, aspects of human well-being at the household and community levels within the wider social-ecological system. To compare across social-ecological system categories, we aggregated all 79 respondents across all 10 indicators (Table 1). The mean reported recovery rates show declines in the status of all but forest and pasture lands six months after the earthquakes, but substantial recovery in some of them within a year (Fig. 3). Forest and pasture lands were not heavily damaged in the earthquake, so access to fodder collection and grazing lands remained largely intact. Among the household-based indicators, in addition to the farming system losses, declines persisted in water and sanitation access, housing, and food security. This pattern corroborates the fact that 86% of households reported reduced access to safe drinking water as a result of damaged springs and wells. Access to and participation in community, social, and religious institutions largely recovered, rebounding to at or near their predisaster levels, a reflection of the strength of existing local institutions. The self-reliance indicator also measured perceived reliance on extra-community assistance, together with perceived ability to assist others. Survey results indicated that, even with overall rebound, Dalits continued to have greater reliance on outside NGO and government assistance, reflected in their significantly lower self-reliance scores relative to the other castes at the one-year mark (Appendix 4).

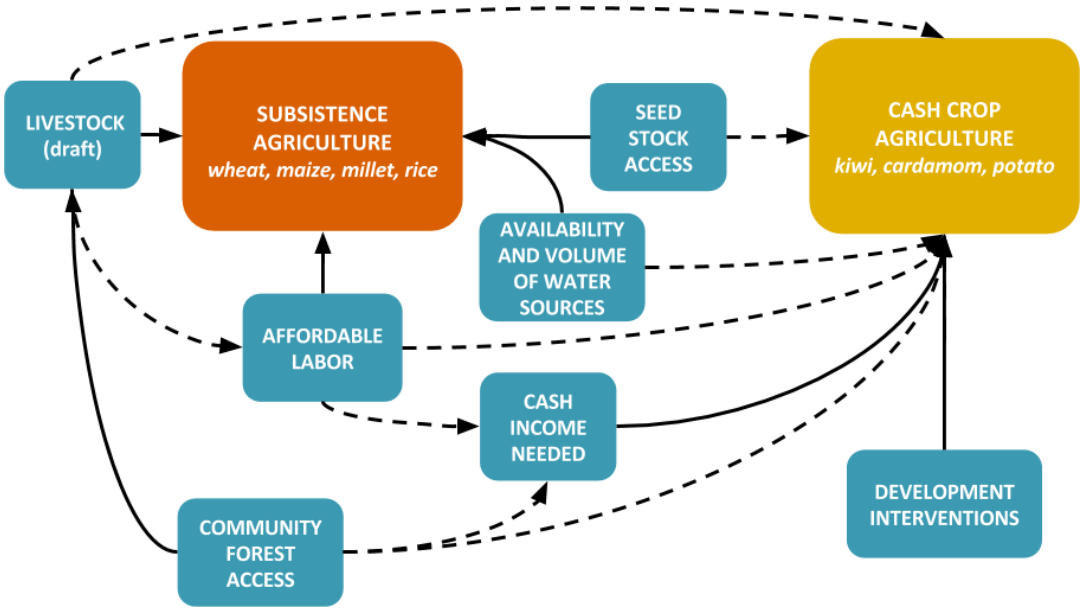
In the days following the earthquake, farmers' reliance on and cooperation with neighbors and community-based groups were critical to survival. Local institutions such as community forest groups efficiently and effectively distributed aid before the government and outside NGOs could help. These traditional recovery strategies have coevolved alongside ongoing transitions and environmental shocks such as earthquakes, landslides, and floods (Berkes and Jolly 2001). The role of community resources can be critical, especially for the poorest households for whom common resources may be the entire asset base (Walker and Jodha 1986). In our study, social-ecological indicators of household and farming systems were perceived to have recovered less than those describing community-based indicators for example, access to forest and pasture lands, cultural and spiritual connectedness, and community institutions. Within one year of the disaster, these resources either returned to, or maintained, some level of "normality" (Fig. 3). This concurs with studies that point to the positive link between resilience and religious and cultural practice (Allison 2016), and how strong social networks and robust community structures and institutions are the hallmarks of resilient systems (Folke et al. 2005, Walker et al. 2006).

Impact and transition pathways in smallholder communities in the Himalayas

These findings are important for highlighting the potential for disasters to hasten ongoing transitions; understanding the significance of, and contradictions in, self-assessed recovery of smallholder households; and generating hypotheses for longer term research on postdisaster recovery and adaptation among such farmers. Based on our case study, we present a schematic to show how the 2015 earthquakes intersected with the ongoing agricultural transitions in these Himalayan smallholder communities (Fig. 5). Focusing on recovery and adaptation within the first year of the shock allowed us to study the strategies of smallholder households when they were most vulnerable, and potentially looking ahead to a more cash-dependent, and possibly more uncertain, livelihood regime. The schematic illustrates how the earthquake affected the availability of subsistence farming inputs, and the specific land and labor requirements of grain crops versus cash crops. Together these changes can reorient the decision pathways for smallholder farming communities. For example, without adequate access to livestock, farmers are labor constrained, which, in our study sites, incentivized the adoption of labor-saving cash crops or other livelihood diversification strategies. The schematic was inductively built up from our specific observations and analysis; it identifies key inputs and their impact on subsistence versus cash-crop dominated farming practices. However, the overall structure of the schematic, with its relational ties between and among inputs and outputs, is hypothesis generating; the direction and weight of specific relationships can and should be tested for other smallholder mountain geographies. Overall, the schematic demonstrates how environmental shocks can act on feedbacks between social-ecological system components and push the systems to an alternate state (see Folke et al. 2004, Walker et al. 2006).

Our study had several limitations that moderate our findings and discussion. First, our small sample left us underpowered to detect any changes pre- and postearthquake with statistical significance. In addition, the social and ecological indicators we chose for the recovery assessment are inherently interdependent, and therefore the various components are better seen as a system rather than as discrete and individually explanatory factors. Second, our sampling design aimed to capture loss and recovery in the short-term aftermath of the earthquakes at a point in time when alleviation of suffering is most critical. Within one year of the earthquake the new crops had not yet gone into the ground; we therefore report on what households were planning to plant as

Fig. 5. Schematic showing relationships between inputs, outputs, and the direction of impacts among those in subsistence and cash crop production in mid-montane Nepal. Solid arrows represent potentially positive feedbacks; dotted arrows represent potentially negative feedbacks. For example, increased access to forest resources enables more livestock because fodder is plentiful; it also implies lower need for cash because some inputs do not have to be purchased. The overall structure of the framework demonstrates pathways through which inputs to the Nepali farm system support the subsistence practices over the adoption of cash crops, or vice versa. The directions of the arrows are specific to our case.



compared to what they had planted before. We cannot extrapolate our findings on perceptions of recovery and adaptation strategies beyond this short term with any degree of certainty. In particular, our hypothesis that the earthquakes have accelerated the transition to cash crops in Dolakha, for some farmers, will require additional verification. Finally, it was clear that all respondents, especially the very poor, benefited from government and donor aid, though some of the aid was not equitably distributed. We were unable to gather a detailed account of how much aid came in, at what times, and from which specific sources; therefore, our discussion of the role that aid played in perceived recovery among the poor is more inference than evidence-based.

CONCLUSION

Natural disasters are pervasive and affect human populations dramatically but asymmetrically. We investigated how mid-hills smallholder households and communities in Dolakha district, Nepal, adapted to the severe impacts of the 2015 earthquakes on their assets, livelihoods, and sense of well-being. The earthquakes interrupted the tightly knit agricultural cycles of smallholder farmers; breaks in these cycles caused subsistence crop farming to contract sharply as households coped with damaged farm structures and inputs, and prioritized the immediate need for cash. An ongoing move away from self-provisioning to a greater engagement with the cash economy appeared to have been hastened in the study communities.

Even within these broadly similar smallholder communities, capacities to recover, and to feel recovered, were highly differentiated one year after the earthquakes hit. Some of the poorest families felt closer to their preshock "normality" because a small amount of aid and increased wage rates were significant benefits to them, whereas some better-off households still felt shattered. These findings suggest that psychosocial elements uncover perceived levels of recovery that may or may not reflect tangible material security. Concurrently, we find that access to community-based physical, social, and cultural resources played a significant role in households' capacity to adapt and recover.

Across the global south, smallholder farming communities are undergoing transformation in response to the pressures of economic globalization and migration. At the same time, these communities are among the most vulnerable to environmental shocks and disaster events. Given these realities, our research suggests that intervention priority be given to supporting endogenous mutual support groups and community-based institutions that are effective as first responders, particularly for very small and poor farm households. These institutions provided critical support in the immediate aftermath of the Nepali earthquakes, well before governments and donors made their presence felt. However, large-scale events like these earthquakes require a multiscalar and sustained, long-term response (Adger et al. 2005). Current government and international agency strategies to reduce vulnerability and risk would benefit from research-based evidence on communities undergoing postdisaster transitions. We present our assessment instrument as one option for harnessing recall data and psychosocial perceptions toward a better understanding of postdisaster change. We hope that the

hypotheses generated through this work (shown visually in Fig. 5) will motivate future research agendas on the relationships and feedbacks between key inputs to smallholder farming systems, and the specific transition pathways that are generated by system-wide perturbations. This type of future work will support more precise recommendations for disaster-related policies and relief and recovery measures.

[1] Examples include the Rockefeller Foundation, United States Agency for International Development (USAID), The Organisation for Economic Co-operation and Development (OECD), European Union, and Department for International Development (DFID).

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/9909

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Appendix 1. Study site characteristics

Table A.1. Summary of demographic and socio-economic characteristics of study sites collected through survey instrument.

	Sundrawati (n=39)	Boch (n=40)
Respondent, Age	49 (min 20, max 80)	51 (min 22, max 78)
Household, Size	4.97	5.75
Respondent, Gender	n=16 (41%) Female n=23 (59%) Male	n=15 (37.5%) Female n=25 (62.5%) Male
Household, Caste	5.13% Dalit 38.46% Brahmin 41.03% Thami 15.38% Chettri 0.00% Thamang	10.00% Dali 2.50% Brahmin 0.00% Thami 45.00% Chettri 42.50% Thamang
Household, primary livelihoods	82.05% Agriculture 10.26% Cottage industry/industry 5.13% Casual labor (non-ag) 2.56% Service (gov't)	95.00% Agriculture 2.50% Casual labor (non-ag) 2.50% Other
Household, main source of income	64.0% off-farm labor 15.4% sells animals 7.7% shop/business 5.1% remittances 5.1% labor	30.0% off-farm labor 20.0% casual agricultural labor 20.0% sells crops 12.5% sells animals 5.0% remittances 5.0% other 2.5% shop/business 2.5% government

Appendix 2. Research methods

Table 2.1. Summary of methodological approaches and research activities.

Activity	Participants	Sample Size
Survey	*Randomly selected villagers in Boch and Sundrawati VDC examining* Crop productivity and schedules Assessment of property damages Water resources Food security Community institutions and post-disaster community dynamics	*n = 39 Sundrawati, n = 40 Boch*
Interviews	*Experts in* Disaster relief and recovery Soil and water quality Agricultural technology and adoption Kiwi, cardamom and potato farming Climate change and geomorphology Biodiversity and conservation Forestry and forest management Conservation area ranger districts	*n = 24*
	Community leaders of Ward,VDC, and district government offices Community forest user groups Women's groups and cooperatives Agricultural groups and cooperatives	
	Community members and residents of Charikot Sundrawati Boch	*n = 30+*
Focus Groups	Leading farmers in Sundrawati (2) Leaders farmers in Boch Women's owned community forest (Sundrawati) Women's development committee	

Observational	*Events include* Village Development Committee meetings Community Forest Group meetings Cash crop / agricultural technology workshops Festivals including a wedding and a funeral

A3. Survey Questionnaire.

Starting time of survey:_____

Name of District _____
Name of VDC _____
Interview Code _____
Interview date 2016 - DAY: MONTH:

Personal Information

Question #	Question	Response
001	Respondent, Age	_____
002	Respondent, Gender	Male.....1 Female.....2
003	How many members in your family?	
004	What is your occupation?	Open response:

Part I: Livelihoods and Income Diversity

Thank you for that information, now we will ask you about your livelihoods and income diversity.

101	What is the main source of livelihood for your family? (occupation that is carried out for most of the time in a single year) *Check only one*	Agriculture .....1 Remittance…..2 Private firms/NGOs….3 Cottage industry/industry.....4 Business-retail, wholesale etc. .....5 Casual labor (agriculture).....6 Casual labor (non-agriculture).....7 Service (government) .....8 Pension, allowance, interest, etc. .....9 Other (Specify)_____.....10 None…..0
102	What are additional livelihood activities for your household? *Check all that apply*	Agriculture .....1 Remittance…..2 Private firms/NGOs….3 Cottage industry/industry.....4 Business-retail, wholesale etc. .....5 Casual labor (agriculture).....6 Casual labor (non-agriculture).....7 Service (government) .....8 Pension, allowance, interest, etc. .....9 Other (Specify)_____10 None….0
103	What is the main source of cash income?	Sells animals.....1 Sells crops.....2 Off-farm labor.....3 Remittances.....4 Shop/Small Business…..5 Gov't Service…..6 7 Labor (ag)……7 Other (Specify)_____8
104	How are HH members employed? (list by role)	[Family role] [Employment] _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____
105	*BEFORE EARTHQUAKE* – How long ago did your family come to this place? [Or migrated from elsewhere]	More than one generation ago….1 One generation ago….2 Recently migrated…..3 I don't know….0 If possible, approximately what year

106	*BEFORE EARTHQUAKE* - What was the reason for your family to move from their previous settlement/ place? (displacement versus migration)	Natural disasters.....1 Land acquisition by gov't .....2 Conflict .....3 Family separation (Divided ancestral assets) .....5 Lack of facilities: market, education, health, etc.....6 Employment.....7 Food insufficiency…8 Other_____.....9 I don't know…0
107	Was your house damaged or destroyed in the earthquake?	No….0 Yes….1 Partially….2
108	If your house was damaged, what type of structure did you live in immediately after the earthquake?	Tarp….1 A friends or families house….2 A new house….3 Other_____…….4 Cottage…..5 Same house……6 House of local materials (livestock shed; bamboo)…….7 N/A……0 ---------- Next _____ Now_____
109	Where was this structures?	Same place…..1 Own land…..2 Government land…..3 Other private land…..4 Other_____…….5
110	If you moved to a new village, how long?	Yes….1 No….0 For how long?
111	Did you build a new home?	Yes….1 No….0 [If no, why? Check all that apply] Waiting gov't support……1 Confusion on gov't policy/plan…..2 Limited time/busy (work, farm, etc.)…..3 No land…..4 No labor…..5 No money…..6 No materials…..7
112	How safe is your current living situation?	Very safe…..1 Somewhat safe….2 Unsafe….3 I don't know….0 Describe

113	How comfortable is your current living situation?	Very comfortable…..1 Somewhat comfortable ….2 Not comfortable ….3 I don't know….0 Describe
114	What kind of assistance did you **need** right after the earthquake (e.g. food, shelter, money, etc.)?	[check all that apply] 1. Food…..☐ 2. Shelter…..☐ 3. Money…….☐ 4. Healthcare…...☐ 5. Enabling policy…..☐ 6. Technical help…..☐ 7. Other: _____…..☐
115	What kind of assistance do you still **need** now?	[check all that apply] 1. Food…..☐ 2. Shelter…..☐ 3. Money…….☐ 4. Healthcare…...☐ 5. Enabling policy…..☐ 6. Technical help…..☐ 7. Other: _____…..☐
116	What do you think the government should focus on now?	[check all that apply] 1. Agriculture innovation/development…..☐ 2. Enabling policy…..☐ 3. Shelter and rebuilding…….☐ 4. Healthcare…...☐ 5. Coordinate with NGO/iNGO…..☐ 6. Financial support…..☐ 7. Other: _____…..☐

Part II: Property and Crop Use

LAND FARMED (1=own, 2=sharecrop, 3= rent)

		Area of Land ropani	**In whose name is the land?** (M/F)	**Crops grown currently, seeds from where** Paddy=1; maize=2; millet=3; potato=4; wheat=5; veg=5; cardamom=6; kiwi=7 own stock=1; buy local=2; commercial/agrovet=3; gov't=4; NGO=5	**Is this different then before the quake?** = (equals) + (more) - (less) 0 – never before **Other crops grown previously – list below**	**What do you do with them now?** Consume=1 Sell locally=2 Sell to Charikot=3 Exchange=4 Livestock=5	**What did you do with them pre-quake?** Consume=1 Sell locally=2 Sell to Charikot=3 Exchange=4 Livestock=5
201	*Khet (farm)*						
202	*Bari*						
203	*Ghaderi*						
204	*Forest*						
205	*Grazing*						
206	*Khoria*						

Part III: Farm structures: livestock, seeds and irrigation

	Details of Livestock	Do/did you have: Yes……1 No…….0		If change, why? Deceased, purchased etc..
		Currently	Before the earthquake	
301	Cow			
302	Buffalo/bull			
303	Ox			
304	Yak			
305	Goat/Sheep			
306	Pig/boar			
307	Horse/donkey/Mule			
308	Hen/Duck/pigeon/titra			

309	*BEFORE EARTHQUAKE* – Did you have access to grazing grounds?	[check all that apply]	Yes.....1 No…..0 1. Personal (own) traditional grazing.....☐ 2. Community forest/land.....☐ 3. Public/Government grazing.....☐
310	*NOW* - Do you have access to grazing grounds?	[check all that apply]	Yes.....1 No…..0 1. Personal (own) traditional grazing.....☐ 2. Community forest/land.....☐ 3. Public/Government grazing.....☐
311	*BEFORE EQ* - Did you have access to fodder collection sites?	[check all that apply]	Yes.....1 No…..0 1. Personal (own).....☐ 2. Community.....☐ 3. Public/Government.....☐
312	*NOW* - Do you have access to fodder collection sites?	[check all that apply]	Yes.....1 No…..0 1. Personal (own).....☐ 2. Community.....☐ 3. Public/Government.....☐
313	BEFORE EQ – Where did you get seeds for your crops?	[check all that apply]	1. Own stock….☐ 2. Purchased local….☐ 3. Commercial/agrovet…..☐

		4. Provided by gov/ngo…..☐ 5. Don't know….☐
314	NOW - Where did you get seeds for your crops?	[check all that apply] 1. Own stock….☐ 2. Purchased local….☐ 3. Commercial/agrovet…..☐ 4. Provided by gov/ngo…..☐ 5. Don't know….☐
315	How were your seed stocks impacted by earthquake?	Complete destroyed…..1 Partially destroyed…..2 Not destroyed…..3
316	What types of fertilizers do you use?	Organic (compost)……1 Non-Organic/Chemical (e.g.Urea)……2 None…..0 ---------- If on subsistence crops…..3 If on market crops (to sell)…..4 If both…..5
317	Is this different then before the earthquake?	Yes…..1 No….0
318	What types of pesticides do you use?	Organic (compost)……1 Non-organic/chemical (e.g.urea, DPA, potass)……2 None…..0 ---------- If on subsistence crops…..3 If on market crops (to sell)…..4 If both…..5
319	Is this different then before the earthquake?	Yes…..1 No…..0
320	BEFORE EQ - Where did your irrigation water come from?	Local river…...1 Local spring….2 Local pond…..3 Rainfed……4 Other system_____.....5 I don't know….0
321	NOW - Where does your irrigation water come from now?	Local river…...1 Local spring….2 Local pond…..3 Rainfed……4 Other system_____.....5 I don't know….0
322	*If 320 and 321 are different*	
323	BEFORE THE EQ - How did you irrigate your fields?	Personal traditional canal.....1 Collective traditional canal.....2 Improved/government canal….3 Temporary (rain fed) canal.....4 Other (specify)_____.....5 None…….0
324	NOW - What type of irrigation do you use?	Personal traditional canal.....1 Collective traditional canal.....2

		Improved/government canal….3 Temporary (rain fed) canal.....4 Other (specify)_____.....5 None…….0
325	Were your irrigation systems damaged in the earthquake?	Yes….1 No….0 How
326	Who pays for maintenance of your irrigation system?	DDC/VDC…..1 Canal User Collective…..2 NGO Project…..3 Individuals…..4 Other (specify)_____.....5
327	Did the earthquake affect your access to drinking water?	Yes….1 No…..0 I don't know….2 [check all that apply] 3. Decreased quantity…..☐ 4. Decreased quality…..☐ 5. Increased quality…..☐ 6. Increased quantity…..☐ 7. Infrastructure damaged…..☐
328	BEFORE EQ - Where did you get your drinking water before the earthquake?	Local Spring….1 Local River/Stream….2 Bottled….3 Other (specify)_____ I don't know…..0
329	NOW - Where do you get your drinking water?	Local Spring….1 Local River/Stream….2 Bottled….3 Other (specify)_____ I don't know….0
330	Do you maintain a kitchen garden for your household's consumption?	Yes.....1 No.....0
331	What do you grow in your garden?	[check all that apply] 1. Leafy green…..☐ 11. Cabbage…..☐ 2. Cauliflower…..☐ 12. Pumpkin…..☐ 3. Potato….☐ 13. Ginger…..☐ 4. Onion…..☐ 14. Lentils…..☐ 5. Garlic…..☐ 15. Pea…..☐ 6. Tomato…..☐ 16. Chili…..☐ 7. Cucumber…..☐ 17. Coriander…..☐ 8. Fruits (which)_____☐ 18. Turmeric…..☐ 9. Herbs…..☐ 19. Sesame…..☐ 10. Beans…..☐ 20. Radish..... ☐ 20. Other _____☐
332	Who maintains the garden?	Male head / husband…..1 Female head / wife…..2 Husband & wife…..3 All / family…..4

		Women in family…..5 Child / children…..6 Other (specify)_____.....7
333	How important is the garden for feeding your family?	Very important…..1 Somewhat important…..2 Not important…..3 I don't know…..0
334	Has reliance on home grown food increased or decreased over last 10 years?	Increased.....1 Decreased.....2 No change……0
335	Has reliance on home grown food increased or decreased in the year since the earthquake?	Increased.....1 Decreased.....2 No change…….0
336	Does the family **buy** other foods (other than homegrown)?	Yes.....1 No.....0 [If yes, check all that apply] 1. Staples (eg: sugar, tea, oil, dhal, etc.)…..☐ 2. Maize…..☐ 3. Wheat…..☐ 4. Millet..... ☐ 5. Rice…..☐ 6. Potato…..☐ 7. Veg…..☐ 8. Meat…..☐ Other_____…..☐
337	Was your food storage system impacted by the earthquake?	Yes….1 No….0 Don't know…2 How
338	Immediately following the earthquake (during initial rescue and relief period), how did you get food?	[Check all that apply] 1. Own food…..☐ 2. Communal food….☐ 3. Relief food…..☐ 4. Buy at shop…..☐ 5. Other_____
339	BEFORE EQ – Did you exchange labor to assist with farming activities?	Yes…..1 No…..0 [check all that apply] 2. Exchange labor…..☐ 3. Hired labor…..☐

340	NOW – Do you hire labor to assist with farming activities?	Yes….1 No….0 [check all that apply] 2. Exchange labor…..☐ 3. Hired labor…..☐
341	Have you changed any farming practices due to the earthquake?	Yes….1 No.....0 [check all that apply] 2. New crops…..☐ 3. New seed source…..☐ 4. New animals…..☐ 5. New farm buildings…..☐ 6. New terraces or beds…..☐ 7. New infrastructure…..☐ 8. Left Fallow…..☐ 9. Other_____☐
342	Would you implement anything different now after the earthquake?	Yes…1 No….0 What
343	Immediately following the earthquake, how did you use your field?	***Khet*** 1. Fallow…..☐ 2. Planted, but less…..☐ 3. Planted, but same…...☐ ***Bari*** 1. Fallow…..☐ 2. Planted, but less…..☐ 3. Planted, but same…...☐ 4. Build structure (house/shed)….. ☐
344	As a farmer, what gov't policies and programs have you participated in or benefited from?	Capacity building…..1 Materials…..2 Technical assistance, farming practices…..3 Technical assistance, water…..4 Technical assistance, seeds…..5 Subsidies……..6 Grants…..7 Loans…..8 Other_____.....9

Part IV: Institutions, Community Property and Natural Resource Management

And now we would like to think about your community more broadly.

Question #	Question	Response
401	Are you or someone in your family a member of community networks on your village?	Yes …….1 No.....0 [Check all that apply] 2. Community Forest…..☐

		3. Farmers…..☐ 4. Women's…..☐ 5. Co-operatives…..☐ 6. User groups……☐ 7. Other_____……☐

	(Post-earthquake) Did you receive any of the following items from the following institutions?	Money (A) (how much)	Food (B) (how much, what kinds)	Materials (C) (how much, what kinds)
	Plan=1 Red Cross=2 Societies=3 Political Party=4 Religious=5 Government=6			
404	**Relatives + Local people/friends + society**			
405	**Local cooperatives/organizations (comm.forestry/womens groups etc) + Bank or Financial institution**			
406	**Government bodies (national) + (local/district)**			
407	**NGOs + International NGOs**			

412	What types of aid were most useful?	Open ended
413	Do you feel the government met your expectations regarding support during rescue and relief?	Open ended Very highly met…..1 Somewhat met…..2 Not at all met…..3 I don't know….0
414	Do you feel the government is meeting your expectations during reconstruction?	Open ended Very highly met…..1 Somewhat met…..2 Not at all met…..3 I don't know….0

415	Were you able to help others immediately following the earthquake?	Yes…..1 No……0 How

Part V: Resilience Assessment

We would now like to ask you to report on a series of short statements that describe how different elements of your life have changed from before the earthquake to now…		Immediately following EQ (0-6 months)					6 months to 1 year after EQ (until now)				
		Impr	Incr	Decl	Decr	Stayed the same	Impr	Incr	Decl	Decr	Stayed the same
501	The productivity of my farm in terms of food production (quantity for consumption)										
502	The productivity of my farm in terms of cash crop production (for selling)										
503	The quality of crops that I produce										
504	The diversity of the crops that I produce										
505	The use of chemical pesticides in my farm										
506	The use of machines on my farm										
507	The use of chemical fertilizers in my farm										
508	The storage system of my seeds for planting										
509	Erosion issues around my farm										
510	My access to drinking water										
511	My access to irrigation water										
512	My irrigation system										
513	The status of my livestock herds										
514	My access to grazing lands										
515	My access to forest resources										
516	My access to a safe housing structure										
517	My access to a comfortable house structure										
518	My farm structures										
519	My income from local off-farm occupations (crafts, labor)										
520	The amount of money I receive from remittances										
521	My family's access to local schools										
522	My access clean toilets										

		Impr	Incr	Decl	Decr	Stayed the same	Impr	Incr	Decl	Decr	Stayed the same
523	My access to water for washing/cleaning										
524	My family's access to local health facilities										
525	The number of months I can provide food for my family from the farm										
526	The number of days I felt my family did not have enough to eat										
527	My fear of earthquakes or natural disasters										
528	My ability to cope with future earthquakes/landslides										
529	My participation in festival events										
530	My participation in local community groups										
531	My ability to visit with non-local friends and neighbors										
532	My capacity to help with rebuilding efforts										
533	My reliance on INGO/NGO aid										
534	My reliance on local institutions										
535	The use of livestock on my farm										
536	The physical health of me and my family										

537	**In terms of earthquake impact, how do you feel your family fared compared to other families in your community?**	Describe	Much better….1 Somewhat better….2 Equal……3 Much worse ….4 Somewhat worse…5 Don't know…..0
538	**In terms of earthquake reconstruction, how do you feel your family fared compared to other families in your community?**	Describe	Much better….1 Somewhat better….2 Equal……3 Much worse ….4 Somewhat worse…5 Don't know….0

Appendix 4. Earthquake impacts to social and ecological systems

Figure A4.1a. & 4.1b. Box plots showing the distribution of adaptation and recovery scores at time "1 Year After EQ" between (a) castes and (b) the presence or absence of cash crops in farming systems. The variability within these groups vary, and highlights the range of resilience perceptions, even if the median is similar across groups. The box contains the middle 50% of the data, the upper edge of the box indicates 75th percentile of the data and the lower edge indicated 25th percentile. The black line inside the box is the median and the ends of the horizontal lines, the "whiskers", represent minimum and maximum values. Plots showing analysis of community and household level variables are available upon request.

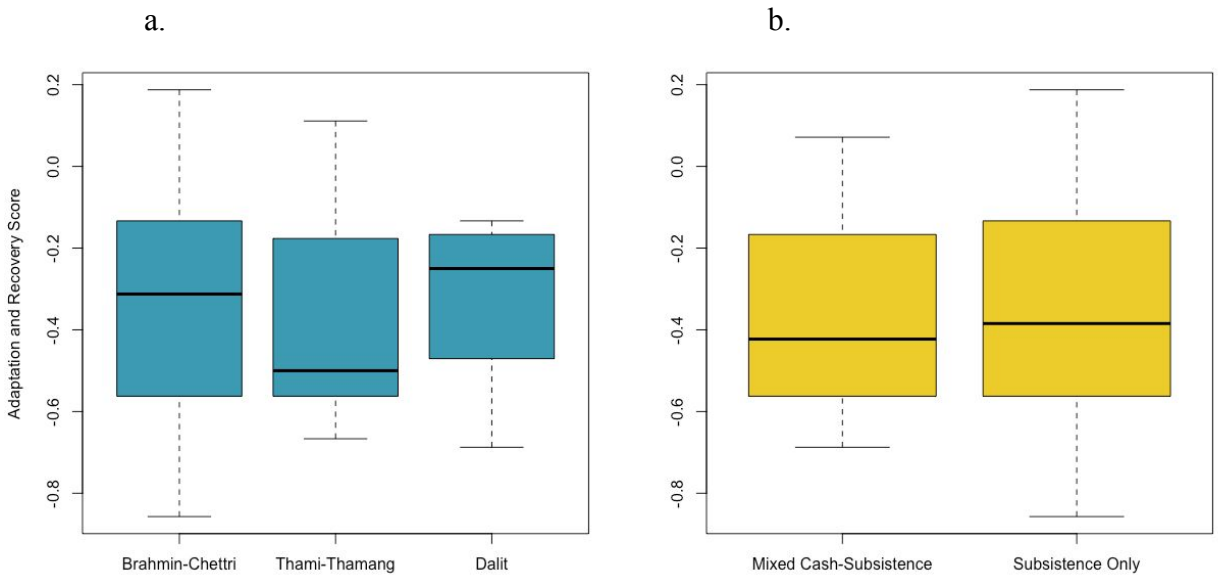

Figure A4.2. Plot of 'self-reliance' adaptation and recovery assessment scores at "0-6 Months After EQ" and "1 Year After EQ" by caste.