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Navigating multidimensional household recoveries following the 2015 Nepal earthquakes

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ABSTRACT

Natural disaster recovery is multidimensional and takes time depending on vulnerabilities. Change occurs as households embedded within integrated social and environmental systems adapt or transform. We focus on the April/May 2015 Nepal earthquakes to understand rural natural disaster recovery. We conducted household surveys on critical earthquake impacts and recovery trajectories with 400 randomly selected households in four clusters of settlements in two districts with catastrophic impacts to all houses and infrastructure. To track rapid change in the short-term, we completed surveys at two intervals—approximately 9 months and 1.5 years. Using non-metric multidimensional scaling (NMDS) ordination, our analysis explores relationships among critical recovery indicators, households, and clusters of settlements. Disaster recovery for these rural mountain households and settlements was spatially and culturally heterogenous, context specific, and changing over time, for better and worse. First, households dependent on place-based agropastoral livelihoods had more challenges recovering compared to households with more diverse market-based livelihoods. Second, the experiences of households in displacement camps were distinct from non-displaced households. Third, accessibility was a determining factor in recovery but not consistently. Fourth, households in the planned dam inundation zone were stagnant waiting for relocation. We presented results to research participants and stakeholders 2.5 years after the earthquakes in a series of research return workshops, which linked the results of our quantitative analysis with study participant experiences and perspectives. Our research contributes to the disaster and development aid literature in four ways by: 1) providing a unique dataset with a random sample over two time intervals collected immediately following a natural disaster; 2) offering a methodology that documents and analyzes recovery as a multidimensional phenomenon; 3) empirically illustrating linear and non-linear disaster recovery dynamics; and 4) capturing the complexity of variation at the household and settlement levels while also identifying patterns that resonate on the ground.

1. Introduction

Natural disaster recovery is a multidimensional phenomenon that can take years, or even decades. Change occurs in the short-term immediately following the event and over time. We seek to understand how rural mountain households embedded within integrated social and environmental systems recover from these disturbances and their cascading effects. We use the catastrophic 2015 Nepal earthquakes as a case study. During April and May 2015, earthquakes and their aftershocks killed 8,790 people and injured more than 22,300. Assessments showed that the earthquakes damaged or destroyed 761,827 private houses and government buildings and approximately 30,000 classrooms (Government of Nepal, 2015; Rasul et al., 2015). There have also been more than 400 earthquakes and aftershocks and 4,000 landslides since the events. Nepal's National Planning Commission estimated that the total value of disaster effects (damages and losses) caused by the earthquakes is NPR 706 billion or US$ 7 billion pushing an additional 2.5–3.5 percent of the Nepalese population into poverty in 2015 and 2016 (Government of Nepal, 2015). Although Nepalese government agencies and international aid organizations quickly mobilized to assist communities affected by these earthquakes, their efforts faced a wide range of challenges, resulting in varying levels of recovery both within and between communities.

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There is a dearth of quantitative social science research on the time immediately following these events and the long-term, especially how lessons learned from one disaster can be applied to the next and can facilitate interdisciplinary communication (Doughty, 2012; Hoffman, 2016; Jones & Faas, 2017; Oliver-Smith & Hoffman, 2002). The lack of robust empirical research on the character of short and long-term recovery makes it difficult to compare one context to another. It also impedes the linking of information across disciplines to address more complex interconnected social and environmental problems. Our research thus takes a comparative approach, examining short-term recovery across multiple sites at two short-term time intervals. We studied 400 randomly chosen households from four severely-impacted clusters of settlements (100 households/settlement) to understand the heterogeneity of recoveries experienced by households with differing accessibilities, market integration, and humanitarian aid. The earthquakes damaged or destroyed nearly all houses and settlement infrastructure at these sites; however, recovery outcomes differed by household and settlement. We utilize a multivariate statistical technique, non-metric multidimensional scaling ordination, to explore recovery trajectories over two time points during the two years following the earthquakes. We also contextualized the findings at 2.5 years in a series of multi-scale research return workshops. We carried out these workshops at the local scale with newly elected government officials and on the national/international scale with representatives from national and international non-governmental organizations (NGOs) and agencies, academics, and the media. The local government officials also participated in the national workshop.

We define "recovery" as extending from the immediate relief and restoration, and improvement where appropriate, of basic services directly following the natural disaster to the longer-term reconstruction of living conditions and livelihoods (and potential improvement, where appropriate) which can overlap and take many years, depending on context (Kates, Colten, Laska, & Leatherman, 2006; Hoffman, 2016, 2012; UNISDR, 2009; Shaw & Sinha, 2003). These phases are fluid. Externally imposed conceptions of recovery phases may differ from those experienced by survivors (Barrios, 2016a, 2016b; Casagrande, McIlvaine-Newsad, & Jones, 2015; Gamburd, 2013; Zhang, 2015). Time compression is the primary difference between natural disaster recovery and regular development (Olshansky, Hopkins, & Johnson, 2012). Households and settlements in disaster contexts are never completely stable and are driven by power and history (Barrios, 2016a); therefore, we consider rebounding from the earthquakes as dynamic processes with variation within and across settlements with different states prior to the earthquakes.

We assembled 34 critical recovery indicators and measured each at two points in time: 9 months (phase 1) and 1.5 years (phase 2) following the earthquakes. Our recovery indicators were chosen based on prior ethnographic research in the study area and in consultation with local collaborators and community leaders, including: rebuilding of homes, recovery of livestock and herding practice, recovery of agricultural practice, ability to work in wage labor or tourism, and access to electricity and communications technology. We then used these indicators to explore patterns among households related to earthquake impacts and recovery trajectories. This multivariate approach matches the multidimensional character of disaster recovery, helping to articulate key interplaying factors contributing to natural disaster resilience during the ephemeral time immediately following the natural hazard, while integrated social and environmental systems are recovering or reorganizing. The diversity of indicators considered may also illustrate poorly understood factors influencing the transformation of household ways of life following a major disturbance.

Addressing natural disaster recovery as a multidimensional phenomenon (Oliver-Smith, 2002) compels researchers to consider many different factors and their interactions. We therefore used non-metric multidimensional scaling (NMDS) to analyze quantitative data on recovery indicators. NMDS is a statistical method widely used in ecology to analyze complex datasets comprising many variables and to identify underlying patterns of variation. For example, in a survey that includes many recovery indicators, NMDS can be used to identify households that exhibit similar patterns of recovery and explore how specific indicators contribute to those patterns. NMDS is similar to other exploratory techniques like principal components analysis, multiple correspondence analysis, and multidimensional scaling, which have been used in previous studies to identify regime shifts in the integrated human and natural systems of Bali rice farms and water management institutions (Lansing, Cheong, Chew, Cox, & Ho, 2014), examine associations among multiple forms of monetary and material wealth and livelihoods in low- and middle-income countries (Hruschka, Hadley, & Hackman, 2017), and document cultural knowledge about climate change and adaptation in coastal communities (Paolisso et al., 2012).

We argue that disaster recovery for rural mountain households and settlements in Nepal is spatially and culturally heterogenous, specific to context, and changing over time, for better and worse. Our results indicate substantial geographic variation in recovery across the sites, including both positive and negative changes over time. Yet, we were also able to identify several common patterns in recovery. First, households dependent on place-based agropastoral livelihoods had more challenges recovering compared to households with more diverse market-based livelihoods. Second, the experiences of households in displacement camps were distinct from households that were not displaced. Third, accessibility determined recovery but not in a consistent or strong way. Fourth, households in the planned inundation zone of a dam were stuck in a liminal state, unable to rebuild but yet to be relocated. At 2.5 years after the earthquakes, research participants and key consultants validated these results and added contextualization. Our study makes four contributions to the literature on disaster recovery and development aid: 1) we provide a unique dataset with a random sample of 400 households over two time intervals collected immediately following a catastrophic natural disaster; 2) our methodology documents and analyzes recovery as a multidimensional phenomenon with more than 30 recovery indicators; 3) our study empirically illustrates linear and non-linear dynamics which are often theorized but not empirically demonstrated; and 4) we developed a method that captures the complexity of variation at the household and settlement levels but also identifies patterns that resonate on the ground. This approach can be used by government, aid practitioners, and local communities to better understand variation in recovery among households and settlements, as well as the factors driving positive and negative outcomes.

2. Multidimensional disaster recoveries

2.1. Households embedded in integrated social and environmental systems

Our broader research focuses on the contributions of five household "domains of adaptive capacity" (biophysical impacts and mitigating household characteristics) to natural disaster recovery: *hazard exposure, institutional participation, livelihood diversity, connectivity, and social memory*. Borrowing from the resilience literature (Walker et al., 2006), we selected the five domains using the "rule of hand," which advises choosing three to five key elements to best understand integrated social and environmental system function and change. Including too many domains can make the dataset too "fuzzy." We selected our domains based on prior work by DiGiano & Racelis (2012) and Cutter (2016a), extensive previous ethnographic and survey research in Nepal by the authors (e.g., Spoon, 2011, 2012, 2013, 2014a, 2014b), and a pilot study. We represent each domain by multiple variables identified through long-term ethnographic research and collaboration with the communities in the study area. Our research then explored the five selected domains on the household level using linked quantitative and qualitative methods. We followed household demographics, settlement demographics, and recovery indicators over time using these approaches. Here we focus on the recovery indicators. Subsequent research will focus on associations between the five domains of adaptive capacity and the recovery indicators analyzed here (see Spoon, Gerkey, Chhetri, Rai, & Basnet, 2020; Spoon et al., 2020; Spoon et al., 2020).

We take an integrated social and environmental systems approach that addresses interdependencies between human populations and the environment containing dual feedbacks (Buergelt & Paton, 2014). This framework facilitates interdisciplinary thinking and dialogue, engaging both natural and social sciences around common questions, data collection, and analysis techniques. It is also simultaneously context specific and longitudinal, allowing us to elucidate temporal dynamics (Cutter, 2016b; Liu et al., 2007). We selected the household level as our primary unit of analysis. We define a household as a physical residence under one roof where household members typically, although not exclusively, share economic resources and have kinship relationships.[1] We then view the settlement and clusters of settlements as secondary foci. We consider settlements as clusters of resource users in the same watershed. Many of the impacts we are measuring occur at the household level; the household is where aid and government relief are coordinated and monitoring and evaluation often occur at the household level. In this study, the household is a key space to understand how multiple factors contribute to recovery outcomes. It is therefore a key interface to understand integrated social and environmental system dynamics.

2.2. Resilience and transformations in everyday life

Whether or not a household has the adaptive capacity to be resilient to a natural hazard or transforms into another configuration depends on how it absorbs and reacts to the shock of the disturbance. After it absorbs the shock, it is considered resilient if it generally retains essential structures, processes, and feedbacks, and is capable of self-organization, learning, and adaptation (Adger et al., 2005; Lansing, Cheong, Chew, Cox, & Ho, 2014; Scheinert & Comfort, 2014; Walker et al., 2006). We borrow from Jones and Murphy (2009) to further define resilience to natural hazards as the intended sense of both adaptation and recovery. Resilience includes the ability to adapt to the demands encountered during and after the disaster (Saunders & Becker, 2015). In these contexts, resilience is often contingent on human agency (Adger, Hughes, Folke, Carpenter, & Rockström, 2005; Gunderson, 2010; Oliver-Smith, 2009). Human intervention can also build resilience into a system and generate diversity in disturbance response (Liu, Dietz et al., 2007). Barrios (2016a, 2019) cautions that a resilience approach should not prioritize returning to the same state as before the disaster, for this approach risks ignoring the role the system played in creating the disaster in the first place. Likewise, a resilience approach should neither accept disaster as given, nor disregard problematic systems and root causes, such as the vulnerabilities that trigger a disaster. We also want to make sure our use of the term resilience and the scale at which we assess it parallels the ways the term is used in practice and not only theoretically to amplify impact (Welsh, 2014). It is also our intention to traverse the academic and practitioner divide by employing terms utilized on the ground (Browne, Marino, Lazrus, & Maxwell, 2019).

Externally enforced conceptions of resilience can also be a vehicle for forwarding neoliberal policies and agendas (Barrios, 2016a; Parson, 2016). Indeed, disaster risk reduction and response are often driven by development practices prioritizing economic growth over social and environmental values (Oliver-Smith, 2016). We also consider whether these externally driven forms of risk reduction and response may be a trap which causes a population to wait for help rather than be proactive; there was some evidence of these dynamics in our results.

When an extreme external disturbance, such as a major earthquake, causes the household, settlement, or social and environmental system to reach a critical threshold, new configurations may emerge. This acute transformation may stimulate significant changes in everyday life. We generally define a household level transformation embedded within an integrated social and environmental system as a change in household and settlement level human-environment dynamics significantly altering the human impact on and relationship with the physical landscape, which includes essential structures, processes, and feedbacks, such as a shift from relying on herding and farming to wage labor outside the area. This may include outmigration, an intensification in resource use, or a switch from subsistence to market reliance or vice versa. A major disturbance such as an earthquake may also drive households and settlements to enact more or less sustainable environmental practices (Xu, Lu, Zuo, & Zhang, 2014).

Previous scholarship focuses on the resilience and transformation of higher order integrated social and environmental systems to less severe and acute ecological or economic perturbations over time, and how to identify critical slowing down or tipping points, potentially moving the system beyond a threshold causing a transformation (e.g. Burkhard, Faither, & Müeller, 2011; Eason, Garmestani, & Cabezas, 2014; Elmqvist et al., 2004; Folke et al., 2004; Hughes, 1994; Kinzig, Ryan, Etienne, Allison, & Walker, 2006; Scheffer & Carpenter, 2003; Scheffer, Carpenter, Foley, Folke, & Walker, 2001; Streeter & Dugmore, 2013). This study thus addresses gaps in the resilience and transformation literature by illustrating household variation in recovery experiences after acute, extreme disturbances and related cascading effects.

Broadening out from a natural disaster focus, recovery, resilience, and transformation in our study can also be viewed in relation to the Sustainable Livelihood Framework, especially in the Global South (e.g., Sudipta et al., 2020; Silva et al., 2020; Pigott-McKellar, Pearson, McNamara, & Nunn, 2019). From this frame, sustainable livelihoods exist in contexts of vulnerabilities; they have the elasticity to cope and recover from stresses (disturbances) without exploiting their resource and asset base (Kaua, Mutheu, & Thenya, 2019). Our recovery indicators cross-cut with assets including natural resources, agropastoral, and material as well as economic opportunities, such as selling livestock products, wage labor, and participating in tourism. Seen this way, these assets, coupled with others such as social capital (Da Silva, Fernandes, Lmont, & Rauen, 2020), provide resilience to disturbances such as natural hazards. An unsustainable livelihood can thus lead to stagnation or transformation. Our analysis of data from Nepal illustrates certain household characteristics evident in the short-term recovery stage that may provide some resilience to natural hazards and more sustainable livelihoods. It also shows evidence of nascent

[1] The definition of household has been contentious in the reconstruction process, with debates over what constitutes a household that is eligible for subsidies. Our definition mirrors that one used in the local censuses we drew upon that were collected after the earthquakes by the government.

transformations in everyday life triggered by this acute disturbance.

3. Context

3.1. Nepal and the 2015 earthquakes

Rural Nepal offers an example of a biophysically uncertain disaster context in mountain ecosystems where a large portion of the population relies on subsistence ago-pastoralism, hunting, and forest product collection. There are also many examples of nascent market integration depending on accessibility to goods and services. Nepal also has a strong tradition of decentralized governance related to natural resources. As in similar contexts (Gamburd, 2013; Gunderson, 2010; Kates, Colten, Laska, & Leatherman, 2006; Oliver-Smith, 2012; Schuller & Morales, 2012; Schuller, 2015, 2012; Willey, 2015), the disaster has the potential to be a "focusing event" (Birkland & Warnement, 2014) or "revealing crisis" (Love, 2016), amplifying pre-existing social, economic, and political inequalities. This is especially relevant considering Nepal's fragile political and economic states after a recent revolution (2006), its reliance on aid from China, India, among others, and the proliferation of INGOs and NGOs in the country before and after the earthquakes. Natural hazards are also increasing in mountain regions similar to Nepal (Zimmermann & Keiler, 2015).

Nearly 80% of Nepal households rely on subsistence agriculture, pastoralism, and the collection of timber and non-timber forest products in largely geographically isolated plain, hill, and mountain areas (Whelpton, 2005). Development agencies proliferated in Nepal before the disaster (Jones, Oven, & Wisner, 2015) and political instability characterizes much of Nepal's recent history, from a decade of civil war (1996–2006) to the 2006 revolution. The lack of locally elected governments for two decades until 2017 has been a particularly detrimental factor to service delivery, giving voice to local communities, and in institutionalizing certain processes and systems, such as disaster preparedness (Jha, 2016). A contested new constitution was signed in September 2015 after the earthquakes. In rural areas, community forestry fostered a strong tradition of decentralized, participatory rule-making, and environmental monitoring. Certain households also created connections through tourism and wage labor abroad that circumvent their reliance on the state for resources (Manandhar, 2015; Spoon, 2011, 2012; Rasul et al., 2015).

The Nepal Government raised four billion U.S. dollars in the immediate relief phase after the April/May 2015 earthquakes; however, it showed some lack of state capacity by initiating the rebuilding program nine months after the event. Within the first three years after the earthquakes, much of the funds remained unspent and difficult to access. The inability of the state to respond to natural disasters is well documented in other contexts (e.g., Carlin, Love, & Zechmeister, 2014; Khosa, 2014; Jalali, 2002). As evident in recovery in Nepal and elsewhere (e.g., Epstein et al., 2018; Le Masson, 2015), the distribution of aid by the government and coverage by INGOs and NGOs has also been difficult to centrally track and coordinate. The majority of aid was distributed during the immediate relief phase following the earthquakes in more accessible areas, a pattern typical in state response to natural disasters in general (e.g., Platt & Drinkwater, 2016; Vallance & Carlton, 2014; Doughty, 2012). Some clusters of settlements in our study were waiting for aid or resettlement before taking more proactive steps to improve their situations. Others did not wait for the assistance but instead cooperated to help one another recover. These examples reflect the wide variation in recovery outcomes; this variation is one of the main challenges for those responding to these catastrophic events and their cascading effects.

3.2. Study sites

In the spirit of comparative research, we selected two districts, Gorkha and Rasuwa, as study sites to explore variation. Both had severe earthquake impacts—Gorkha was the epicenter of the April 2015 earthquake and Rasuwa was decimated by earthquake-related landslides and had the highest per capita deaths (Fig. 1). The Nepal Government officially considered Gorkha and Rasuwa Districts as two of the 14 earthquake-impacted districts. Selecting more than two districts was not possible at the time due to the inaccessibility of most rural settlements impacted by the earthquakes and difficulty in the field reaching certain communities. Within each district, we selected two administrative areas, called Village Development Committees (VDCs), to contrast. VDC boundaries often follow the physical landscape and group together settlements as clusters of resource users sharing a watershed or common topography (e.g., settlements that stretch from the top of a hill down to the river). Our study thus uses these clusters of resource users as the research universe or boundaries of the integrated social and environmental systems in the study areas. Exploring variation at the settlement level is important for ensuring a proper context for interpreting household variation. Within each VDC are settlements with internally and externally defined boundaries where households share physical infrastructure, common-pool resources, and work exchange. Our team had connections with some of the settlements and local leaders through previous conservation and development projects conducted by the international non-governmental organization (INGO) The Mountain Institute.

We conducted a pilot study in November and December 2015 to select study sites in these districts and develop a set of recovery indicators. Our team met with local leaders and government representatives to assist with site selection and obtain an accurate census to draw a random sample from. Our primary criteria were to select one VDC in each district that was accessible by road and had a strong presence of INGOs and national non-governmental organizations (NGOs) after the earthquakes (Aaru Chanaute and Gatlang). Our secondary criteria were that these VDCs had more heterogeneous livelihoods and less reliance on natural resources. Our primary criteria for the second VDC in each district included inaccessibility by road, less INGOs, and NGOs (Kashigaun and Haku). Our secondary criteria included livelihoods relying more on the use of natural resources, primarily marginal herding and farming in non-irrigated fields, and outmigration for wage labor. Each District also had one VDC impacted by large-scale hydropower projects (Aaru Chanaute and Haku). One of the VDCs had entire settlements decimated by the earthquakes with most residents being relocated to displacement camps (Haku). In early 2017, the Nepal Government reorganized the VDCs into larger municipalities. We continue to utilize the four groups of settlements from the original VDCs even though they are now part of larger municipalities that include several VDCs across much broader physical geographies (Fig. 1).

The two VDCs we selected as representative case studies in Gorkha District were the more accessible Aaru Chanaute (VDC 1) and less accessible Kashigaun (VDC 2). Aaru Chanaute has two tiers of settlements—a concentration of households in the market area and others that depend more on agropastoralism and wage labor. Its population is heterogenous, composed primarily of the Newar, Brahmin, Chhetri, Gurung, and Ghale ethnic groups. Due to its accessibility, there was a host of international aid organizations that provided assistance after the earthquakes. A large planned hydropower project, the Budi Gandaki Dam, will inundate the market area in the coming years. Kashigaun is a rural VDC two-days walk from the road head in Aaru Chanaute VDC. The Gurung/Ghale ethnic group almost exclusively populates the VDC (Macfarlane,

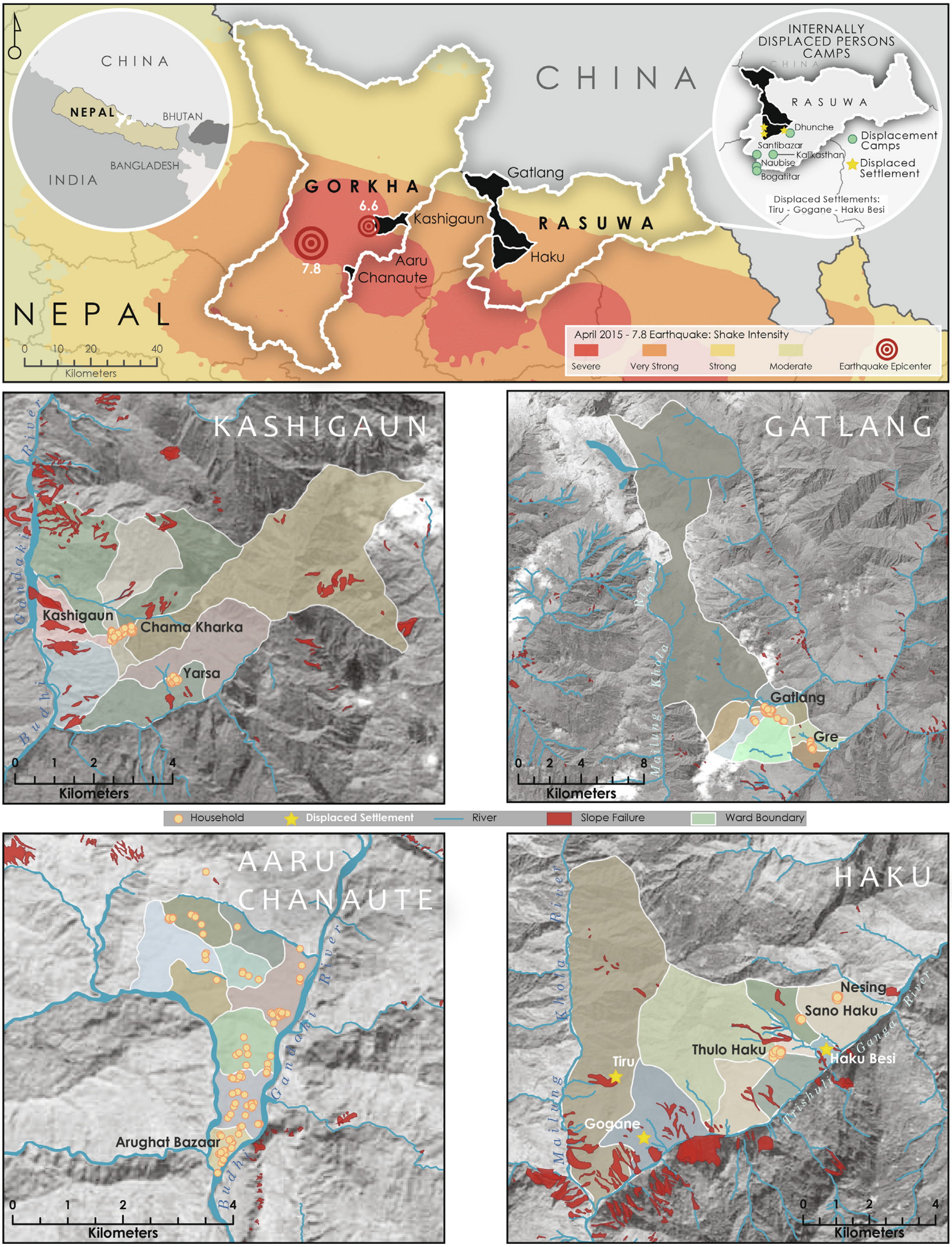

Fig. 1. Map of study area with shake intensity from April 2015 Nepal earthquake with selected Village Development Committees and Internally Displaced Persons Camps. Proximity of settlements to slope failures (landslides) also illustrated (ICIMOD, 2017). Map by Alicia Milligan.

1976; Regmi, 1991), which includes three settlements: Yarsa, Kashigaun, and Chama Kharka. Residents generally practice agropastoralism and work as wage laborers. *Parma* or work exchange and cooperation in agriculture is also a common practice in Kashigaun, which has proven effective in disaster recovery and reconstruction in Nepal (Epstein et al., 2018) and elsewhere (Faas, 2017). After the earthquakes, there was only sparse representation by the aid community in Kashigaun.

We selected Gatlang (VDC 3) and Haku (VDC 4) in Rasuwa. Gatlang is accessible from the road and has two settlements, Gatlang and Gre. The Tamang ethnic group primarily populates the VDC (Campbell, 2013; Fricke, 1993; Holmberg, 1989). Residents practice mostly agropastoralism; however, more recently, working in tourism is a growing livelihood option. Significantly, after the earthquakes, many INGOs and NGOs provided relief materials in Gatlang. Haku is a less accessible, rural VDC, one to two days walk from the road-head. Similar to Gatlang, the Tamang ethnic group generally populates the VDC (Campbell, 2013; Fricke, 1993; Holmberg, 1989). It has seven settlements: Nesing, Sano Haku, Haku Besi, Thulo Haku, Tiru, Gogane, and Mailung. Landslides decimated three settlements. They were completely relocated to seven different displacement camps to the south at significantly lower elevations, inhabited by these households for two years or more (Fig. 1). Blasting for a nearby hydropower project may have also facilitated the landslides triggered by the earthquakes, as in other contexts (Jianguao et al., 2012). Since the disaster, only sparse aid reached those households not displaced from the VDC; INGO/NGO presence is significantly less than in Gatlang. There was also a significant increase in conversion to Christianity in some settlements after the earthquakes.

4. Methods

4.1. Data collection

Our study focused on the earthquake impacts and recovery trajectories at approximately 9 months (36–46 weeks) and 1.5 years (68–78 weeks) following the events. We also carried out research return workshops at the local and national scales at approximately 2.5 years (120–130 weeks). We started data collection nine months after the earthquakes to allow enough time for the national reconstruction program to begin. We conducted a pilot study in 2015 with qualitative interviews and collaboration with local institutions to identify VDCs and recovery indicators, followed by a structured survey, in-depth interviews, focus groups, and infrastructure surveys 9 months and 1.5 years after the earthquakes in each VDC. At 2.5 years, we carried out additional qualitative methods and participant and stakeholder review of results. Here we focus on the results of the structured survey and the interpretation of those results in the research return workshops. We took a collaborative approach, which included capacity building for our Nepali staff and dialogue with the host communities; this type of collaborative approach was utilized in an additional study in nearby districts (Childs, Craig, Dhakal, Donohue, & Hildebrandt, 2018). Through a partnership with the Resources Himalaya Foundation we employed new master's graduates from Tribhuvan University as staff. Our project thus provided concrete training, assisting with future academic and professional opportunities. For each VDC in our project, we selected a random sample of 100 households, utilizing a local censuses collected by VDC staff after the earthquakes and provided to project staff in November and December 2015 during the pilot study.

We consider disaster resilience and recovery as multidimensional (Cutter, Ash, & Emrich, 2014; Cutter, 2016b). Critical recovery indicators in the household survey included 34 variables at two time intervals: home reconstruction and issues trying to rebuild, recovery of agricultural or pastoral or practice, recovery of three types of agricultural fields, standing crops, seed storage, and sale of livestock and agricultural products, recovery of the ability to work as wage labor or in tourism, and access to electricity, cell phones, and internet (see Tables 1 and 2 for full list of variables). Here we focus on these material recovery indicators only. In subsequent analyses, we will add in the other domains of adaptive capacity (biophysical factors and mitigating household characteristics) to better understand recovery dynamics (see Spoon, Gerkey, Chhetri, Rai, & Basnet, 2020; Spoon et al., 2020; Spoon et al., 2020). We recognize that our selected indicators are *tangible* aspects of natural disaster recovery in contexts with agropastoral and small-scale market-based livelihoods, most likely associated with profitmaking (Barrios, 2016a; Schuller & Maldonado, 2016). Our study extends beyond the typical indicators such as the rebuilding of housing units (e.g., Ganapati, 2013; Olshansky, 2005) to touchstones related to the participant household rural ways of life. We recognize that multiple *intangible* aspects of recovery are also key to understanding human well-being and social transformation in these contexts. We therefore supplement our results with insights from our research return workshops, participant observation, and key consultant interviews to assist with contextualization. Additional qualitative aspects of recovery are outside the scope of this article; however, they are analyzed elsewhere (Spoon et al., 2020; Spoon et al., 2020).

Between February and April 2016, we held eight community meetings attended by more than 500 individuals and conducted 400 household surveys with an equal distribution of male and female consultants from the four clusters of settlements and associated displacement camps within Gorkha and Rasuwa. We also gathered GPS coordinates for each household and created maps of the sample's geographic and administrative distribution. Between September and December 2016, the team held nine community meetings attended by more than 700 individuals to return preliminary results and solicit feedback. We re-contacted the 400 participating households for repeat surveys (we re-located 397). We were able to reidentify 357 out of the 400 original respondents from phase 1. In the 43 cases where we were unable to interview the original participant we interviewed 40 alternative household members in the same households. In October and November 2017, our team conducted eight local and national research return workshops with newly elected ward representatives, government agencies, INGOs, NGOs, applied academics, and media to triangulate results and provide contextualization. These efforts included planning and implementing an international workshop in Kathmandu with more than 100 participants, including country level INGO leaders and local government representatives to discuss the broader impacts of the results to earthquake recovery interventions. Our team also participated in various local meetings and events across the entire 3.5 year research duration and conducted informal key consultant interviews with targeted individuals after the research return workshops to assist with the interpretation of findings.

4.2. Data analysis

We analyzed the quantitative survey data and explored relationships among the recovery indicators, clusters of settlements, and displacement camps using non-metric multidimensional scaling (NMDS). This is an exploratory technique that allows us to analyze a wide range of recovery indicators and identify patterns among them, link these patterns to specific recovery indicators, and identify households that exhibit similar patterns of recovery. In order to study changes over time, we include two observations for each household, one at 9 months (phase 1) and another at 1.5 years (phase 2) following the earthquakes, with measures for all 34 recovery indicators at each phase. NMDS examines correlations in the responses to these recovery indicators and identifies a limited number of "dimensions" that represent similar patterns of recovery in the responses given by households across both phases. NMDS allows us to accomplish three important tasks. First, NMDS allows us to combine the information from a large number of recovery indicators and identify patterns among them. We call

Table 1
Recovery indicator results by variable for Axis 1 and Axis 2. Phase 1 and 2 are combined for each variable. Results with R^2 > 0.050 in bold.

Recovery Indicator Variable	Axis 1		Axis 2	
	r (P1&P2)	R^2 (P1&P2)	r (P1&P2)	R^2 (P1&P2)
1. Household having issues trying to rebuild	−0.133	0.018	**0.368**	**0.136**
2. Household able to return to primary house	0.063	0.004	**0.380**	**0.144**
3. Household has access to cell phone	0.010	0.000	0.038	0.001
4. Household has access to internet	0.175	0.030	0.127	0.016
5. Household has access to electricity	0.059	0.004	0.087	0.007
6. No earthquake and connected hazard impacts to *bari* (non-irrigated fields)	**0.673**	**0.453**	−0.048	0.002
7. Some earthquake and connected hazard impacts to *bari* (non-irrigated fields)	−0.088	0.008	0.220	0.049
8. High earthquake and connected hazard impacts to *bari* (non-irrigated fields)	**−0.613**	**0.376**	−0.113	0.013
9. No earthquake and connected hazard impacts to *khet* (irrigated fields)	−0.037	0.001	0.058	0.003
10. Some earthquake and connected hazard impacts to *khet* (irrigated fields)	0.000	0.000	0.043	0.002
11. High earthquake and connected hazard impacts to *khet* (irrigated fields)	0.041	0.002	−0.090	0.008
12. Earthquakes and connected hazards killed standing crops	**−0.551**	**0.303**	−0.099	0.010
13. Earthquakes and connected hazards affected seed storage	**−0.288**	**0.083**	**−0.274**	**0.075**
14. No earthquake and connected hazard impacts to livestock health, behavior, or productivity (primary impact)	**0.433**	**0.188**	**−0.557**	**0.311**
15. No earthquake and connected hazard impacts to livestock health, behavior, or productivity (secondary impact)	**0.282**	**0.080**	**−0.323**	**0.104**
16. Earthquake and connected hazard impacts to livestock health	**−0.330**	**0.109**	**0.495**	**0.245**
17. Earthquake and connected hazard impacts to livestock behavior (primary impact)	−0.201	0.040	0.161	0.026
18. Earthquake and connected hazard impacts to livestock behavior (secondary impact)	−0.185	0.034	**−0.140**	**0.288**
19. Earthquake and connected hazard impacts to livestock productivity (primary impact)	−0.090	0.008	**−0.079**	**0.093**
20. Earthquake and connected hazard impacts to livestock productivity (secondary impact)	−0.209	0.044	**−0.137**	**0.157**
21. Total household lost/recovered bovine (yak, cow, hybrid) – log	**−0.393**	**0.155**	**−0.351**	**0.123**
22. Total household lost/recovered sheep, goats, and pigs – log	**−0.486**	**0.237**	**−0.364**	**0.132**
23. Total household lost/recovered chickens – log	**−0.275**	**0.076**	**−0.527**	**0.278**
24. No earthquake and connected hazard impacts on household ability to keep livestock	**0.685**	**0.469**	−0.214	0.046
25. Some earthquake and connected hazard impacts on household ability to keep livestock	0.063	0.004	0.161	0.026
26. High earthquake and connected hazard impacts on household ability to keep livestock	**−0.724**	**0.524**	0.103	0.011
27. No earthquake and connected hazard impacts on household ability to sell livestock products	**0.505**	**0.255**	0.075	0.006
28. Some earthquake and connected hazard impacts on household ability to sell livestock products	−0.148	0.022	0.062	0.004
29. High earthquake and connected hazard impacts on household ability to sell livestock products	**−0.495**	**0.245**	−0.134	0.018
30. No earthquake and connected hazard impacts on household ability to go for outside work	**0.244**	**0.060**	−0.026	0.001
31. Some earthquake and connected hazard impacts on household ability to go for outside work	−0.146	0.021	0.028	0.001
32. High earthquake and connected hazard impacts on household ability to go for outside work	−0.188	0.035	0.009	0.000
33. No earthquake and connected hazard impacts on household ability to work with tourists	0.083	0.007	0.003	0.000
34. High earthquake and connected hazard impacts on household ability to work with tourists	−0.075	0.006	0.026	0.001

this task "pattern identification." Second, NMDS allows us to examine how specific recovery indicators shape these patterns of recovery. For each of our 34 recovery indicators, NMDS provides measures of the direction and strength of the association with each dimension of recovery, allowing us to interpret the patterns we observe and understand how recovery indicators relate to one another. We call this task "pattern interpretation." Finally, NMDS allows us to determine which households exhibit similar patterns of recovery. For each household in our sample, NMDS generates a value reflecting its association with each dimension of recovery. With these values, we can group households with similar patterns of recovery and explore associations between recovery and household characteristics. NMDS is widely used in ecology to identify patterns of covariation in complex multivariate datasets (e.g., McCune & Grace, 2002; Reyes-García et al., 2013; Rusack et al., 2011; Crona & Bodin, 2006). Unlike many other statistical techniques, NMDS requires minimal assumptions about the relationships among variables and can be used with binary, ordinal, categorical, and continuous variables, making it particularly appropriate for investigating a multidimensional social phenomena such as disaster response and recovery (Hruschka, Hadley, & Hackman, 2017; Lansing, Cheong, Chew, Cox, & Ho, 2014; Paolisso et al., 2012).

5. Results

5.1. Background context

The earthquakes damaged or destroyed the primary home of 396 out of the 400 (99%) randomly selected households across the four VDCs (18% damaged and 82% destroyed). These same households were also unable to return to their homes within nine months after the events. By phase 2, 44% had been able to return to their homes from temporary shelters. A study conducted by The Asia Foundation (2017) found similar results, with 39% returning to their homes at 1.5 years in four other severely impacted districts. All of the infrastructure (micro-hydropower plants, schools, hospitals, health posts, monasteries, temples, and communal buildings) in the VDCs was damaged or destroyed from the earthquakes or related landslides. By phase 2, less than 40% of this infrastructure was rebuilt. There were marked differences at this time in the number of households able to return home across the VDCs—as high as 92% in the less accessible VDC Kashigaun and as low as 8% in the more accessible VDC Gatlang. The earthquakes also forced the relocation of 64 households in the sample (16%) to seven different displacement camps. By phase 2, 63 of these households remained in the camps. There were spatial variations in each VDC as well; there were accessible and inaccessible settlements in each depending on proximity to road, trail, or helipad. By this criterion, 44% (176) of the households in the entire sample were accessible and 56% (224) were inaccessible.

5.2. Pattern identification

Our analysis combines information from 34 recovery indicators across all four VDCs. The majority of our recovery indicators (n = 31) were measured on a binary scale (1 = Yes, 0 = No), the remaining indicators (n = 3) track numbers of livestock lost and were measured on a continuous scale then log-transformed before analysis. To track changes in recovery over time, we include two data points

Table 2
Recovery indicator results by variable for Axis 1 and Axis 2 in phases 1 and 2. Results with R^2 > 0.050 in bold.

Recovery Indicator Variable	Phase 1 (9 months)				Phase 2 (1.5 years)			
	Axis 1		Axis 2		Axis 1		Axis 2	
	r	R^2	r	R^2	r	R^2	r	R^2
1. Household having issues trying to rebuild	−0.092	0.008	**0.247**	**0.061**	−0.176	0.031	0.086	0.007
2. Household able to return to primary house	0.081	0.007	0.077	0.006	0.076	0.006	**0.283**	**0.080**
3. Household has access to cell phone	−0.032	0.001	0.060	0.004	0.079	0.006	−0.009	0.000
4. Household has access to internet	0.167	0.028	0.030	0.001	0.213	0.045	0.092	0.008
5. Household has access to electricity	0.139	0.019	0.006	0.000	0.041	0.002	−0.051	0.003
6. Earthquakes and connected hazards killed standing crops	**−0.499**	**0.249**	−0.157	0.025	**−0.368**	**0.136**	−0.019	0.000
7. Earthquakes and connected hazards affected seed storage	**−0.350**	**0.123**	−0.188	0.035	−0.188	0.035	-0.032	0.001
8. No earthquake and connected hazard impacts to *bari* (non-irrigated fields)	**0.563**	**0.317**	0.056	0.003	**0.515**	**0.266**	0.036	0.001
9. Some earthquake and connected hazard impacts to *bari* (non-irrigated fields)	−0.129	0.017	0.165	0.027	−0.008	0.000	0.175	0.031
10. High earthquake and connected hazard impacts to *bari* (non-irrigated fields)	**−0.499**	**0.249**	−0.181	0.033	**−0.486**	**0.236**	−0.164	0.027
11. No earthquake and connected hazard impacts to *khet* (irrigated fields)	0.033	0.001	0.041	0.002	−0.136	0.018	−0.006	0.000
12. Some earthquake and connected hazard impacts to *khet* (irrigated fields)	0.036	0.001	0.091	0.008	−0.032	0.001	−0.066	0.000
13. High earthquake and connected hazard impacts to *khet* (irrigated fields)	−0.066	0.004	−0.116	0.013	0.157	0.025	−0.020	0.000
14. No earthquake and connected hazard impacts to livestock health, behavior, or productivity (primary impact)	**0.304**	**0.092**	**−0.332**	**0.110**	**0.308**	**0.095**	**−0.363**	**0.132**
15. No earthquake and connected hazard impacts to livestock health, behavior, or productivity (secondary impact)	**0.224**	**0.050**	−0.139	0.019	0.127	0.016	**−0.281**	**0.079**
16. Earthquake and connected hazard impacts to livestock health	−0.190	0.036	**0.284**	**0.081**	**−0.271**	**0.073**	**0.302**	**0.091**
17. Earthquake and connected hazard impacts to livestock behavior (primary impact)	−0.215	0.046	0.118	0.014	−0.072	0.005	0.119	0.014
18. Earthquake and connected hazard impacts to livestock behavior (secondary impact)	−0.177	0.031	0.171	0.029	−0.086	0.007	**0.246**	**0.060**
19. Earthquake and connected hazard impacts to livestock productivity (primary impact)	−0.021	0.000	0.030	0.001	−0.073	0.005	0.086	0.007
20. Earthquake and connected hazard impacts to livestock productivity (secondary impact)	−0.139	0.019	0.036	0.001	−0.096	0.009	0.134	0.018
21. Total household lost/recovered bovine (yak, cow, hybrid) – log	**−0.391**	**0.153**	**−0.348**	**0.121**	**−0.387**	**0.150**	**−0.348**	**0.121**
22. Total household lost/recovered sheep, goats, and pigs – log	**−0.489**	**0.239**	**−0.353**	**0.125**	**−0.476**	**0.226**	**−0.360**	**0.130**
23. Total household lost/recovered chickens – log	**−0.277**	**0.077**	**−0.514**	**0.264**	**−0.263**	**0.069**	**−0.523**	**0.274**
24. No earthquake and connected hazard impacts on household ability to keep livestock	**0.537**	**0.288**	−0.048	0.002	**0.518**	**0.268**	0.169	0.028
25. Some earthquake and connected hazard impacts on household ability to keep livestock	0.030	0.001	0.039	0.002	0.018	0.000	0.169	0.028
26. High earthquake and connected hazard impacts on household ability to keep livestock	**−0.563**	**0.317**	0.023	0.001	**−0.515**	**0.266**	0.017	0.000
27. No earthquake and connected hazard impacts on household ability to sell livestock products	**0.499**	**0.249**	0.144	0.021	**0.268**	**0.072**	−0.131	0.017
28. Some earthquake and connected hazard impacts on household ability to sell livestock products	−0.097	0.009	0.069	0.005	−0.129	0.017	0.083	0.007
29. High earthquake and connected hazard impacts on household ability to sell livestock products	**−0.505**	**0.255**	−0.211	0.044	**−0.237**	**0.056**	0.098	0.010
30. No earthquake and connected hazard impacts on household ability to go for outside work	0.184	0.034	−0.056	0.003	0.167	0.028	0.007	0.000
31. Some earthquake and connected hazard impacts on household ability to go for outside work	−0.092	0.009	0.073	0.005	−0.132	0.018	−0.052	0.003
32. High earthquake and connected hazard impacts on household ability to go for outside work	−0.154	0.024	0.016	0.000	−0.096	0.009	0.050	0.003
33. No earthquake and connected hazard impacts on household ability to work with tourists	0.032	0.001	0.044	0.002	0.077	0.006	−0.143	0.020
34. High earthquake and connected hazard impacts on household ability to work with tourists	0.015	0.000	−0.047	0.002	−0.077	0.006	0.143	0.020

for each household, corresponding to the household's recovery indicators at phases 1 and 2. The resulting household matrix (797 household observations × 34 recovery indicators) was analyzed in the software package "PC-ORD" (McCune & Grace, 2002; Peck, 2016). NMDS examines variation across all recovery indicators for all households in our sample and identifies patterns of co-variation among households and recovery indicators. We call these patterns of co-variation "dimensions of recovery." Our NMDS identified three dimensions of recovery, corresponding to a three-dimensional solution (distance = Bray-Curtis/Sorenson, stress = 17.9, R-square = 0.798, Monte Carlo Test p = .004). We focus our analysis on the first two dimensions, which capture the majority of variation in our recovery indicators. These dimensions can be visualized in a scatter plot ("ordination"), where the x-axis represents the first dimension, the y-axis represents the second dimension (Fig. 2). A household's location on each axis represents its association with each dimension of recovery. Households located near each other in the plot exhibit similar recovery indicators while households located further apart are more different. Thus, the ordination maps households in a multidimensional recovery space, using information from each of the original 34 recovery indicators. See Table 1 to view full results that combine phases 1 and 2.

5.3. Pattern interpretation

Knowing where households are located within the multidimensional recovery space provides limited insight unless we can interpret each dimension of recovery generated by NMDS. To understand how specific recovery indicators contribute to each dimension of recovery, we use two techniques: (1) "vector fitting" and (2) "surface fitting." Vector fitting is used to analyze linear associations between a recovery indicator and NMDS dimensions of recovery, while surface fitting can be used to investigate non-linear associations.

Vector fitting produces two estimates of the association between a recovery indicator and NMDS dimensions of recovery: a correlation coefficient (r) and a measure of model fit (R-square). The correlation coefficient measures the direction of the association (positive/negative/neutral) and the magnitude of the association ($-1 < r < 1$), while the model fit represents the amount of variance captured by the association. We visualize these associations by adding lines ("vectors") to our NMDS ordination plot, with the direction of the line along each axis indicating the direction of the association and the length of the line indicating the magnitude of the association. In an effort to ease interpretation,

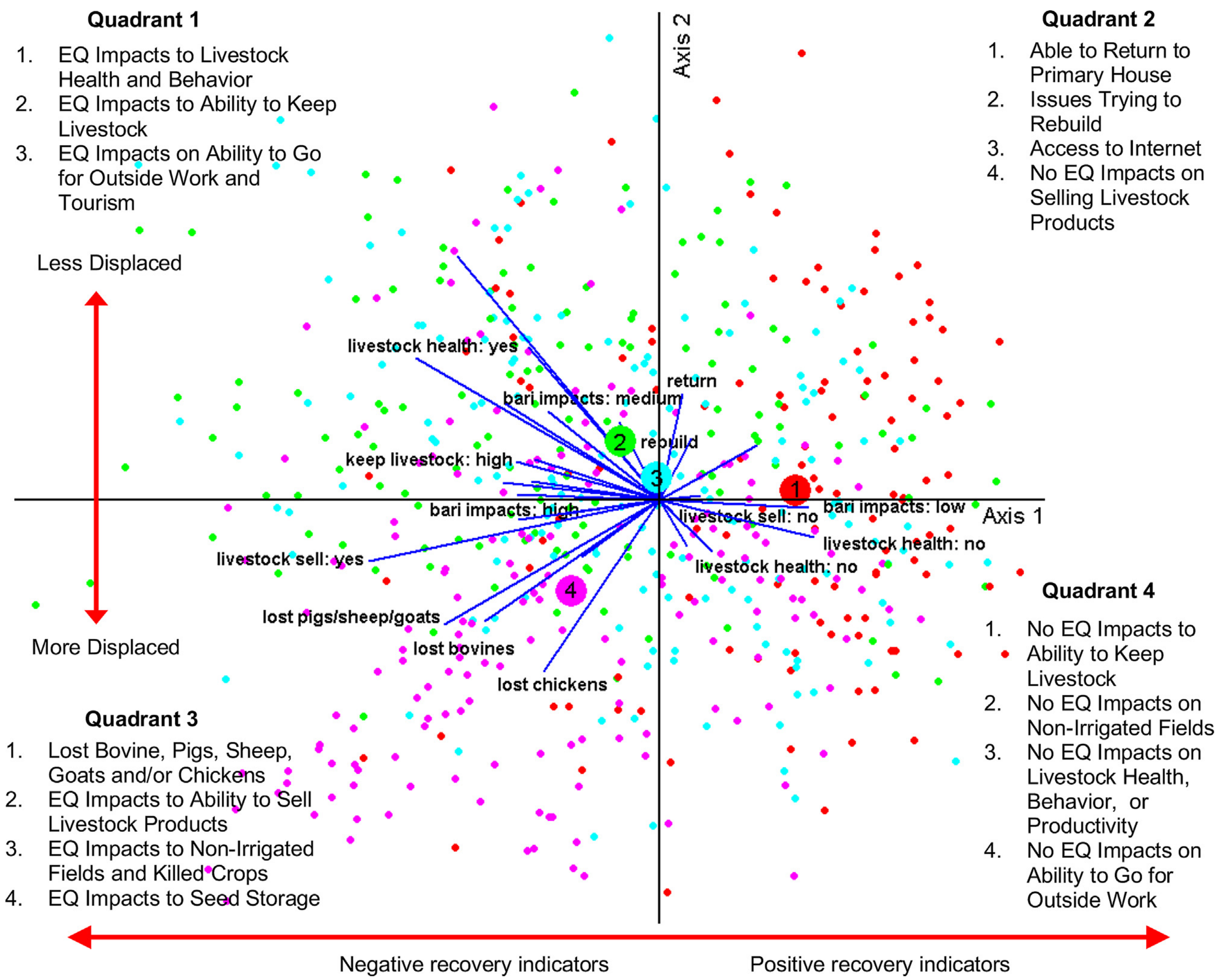

Fig. 2. NMDS scatterplot of recovery indicators for entire sample (N = 397 households) across both time periods with centroid (average positions) of households in each VDC. Lines represent indicators that are most strongly associated with the two dimensions of recovery. Notes added to each quadrant highlight variables that characterize these parts of the recovery space (VDC 1 = Aaru Chanaute; VDC 2 = Kashigaun; VDC 3 = Gatlang; VDC 4=Haku).

we only added lines to the scatter plot for recovery indicators that have strong associations with the two dimensions of recovery.

Examining the association of each recovery indicator with each axis allows us to understand each dimension of recovery. Overall, households from the more accessible and livelihood diverse Aaru Chanaute (VDC 1) are generally in the positive recovery space, while many households in displacement camps from Haku (VDC 4) are almost exclusively in the negative recovery space. Fig. 2 and Table 1 show that increasing values on Axis 1 (quadrants 2 and 4) are generally associated with positive recovery indicators and decreasing values (quadrants 1 and 3) are associated with negative recovery indicators. Negative recovery indicators show stronger associations with Axis 1, suggesting this dimension of recovery identifies households who are struggling. On Axis 2, decreasing values (quadrant 3) are generally associated with households that had catastrophic impacts to both their herding and agricultural livelihoods, including households in displacement camps (all from Haku-VDC 4) and households from all areas that still remained near their villages but were unable to return to their homes from temporary shelters and/or resume their place-based agropastoral livelihoods at phase 2. Increasing values on Axis 2 are associated with households who have been able to return to or remain in their community but are still struggling with the impacts of the earthquakes. These dynamics are easily visible in Fig. 2, where we highlight the average position (centroid) of households in each VDC with phases 1 and 2 combined. Aaru Chanaute (VDC 1) is in the positive recovery space and Haku (VDC 4) is in the negative space. Kashigaun (VDC 2) and Gatlang (VDC 3) are the most similar.

Results from vector fitting suggest that the strongest associations between specific recovery indicators and dimensions of recovery over the two time intervals were for herders and *bari* (non-irrigated) farmers who had the hardest impacts and were recovering slower. All farmers had their crops killed and seed storage impacted and all participating households had their ability to herd and sell livestock products impacted, but in different ways. Households relocated to displacement camps lost the most livestock and had their seed storage impacted; whereas those households that were less displaced had their livestock's health, behavior, and productivity impacted. Lastly, households displaced from their homes but not relocated to camps were having issues rebuilding, such as securing government aid or loans, and restarting their place-based agropastoral livelihoods.

The vector fitting method examines linear relationships between recovery indicators and NMDS patterns of recovery over time; however, previous research on resilience and regime shifts suggests that dynamics in integrated social and environmental systems may be non-linear (Lansing, Cheong, Chew, Cox, & Ho, 2014). To explore non-linear associations, we use an alternate method, called "surface fitting." Rather than generating a single line to indicate the relationship between a recovery indicator and each dimension of recovery (vector fitting), surface fitting generates a series of lines on the ordination plot that can represent both linear and non-linear associations between variables (McCune & Grace, 2002). When these lines run straight in the same direction (parallel), this indicates a linear association. When these lines curve, this indicates a non-linear association. Applying surface fitting to our NMDS ordination of recovery indicators, we obtain an R-square value that can be used to assess the amount of variance captured by the non-linear association between a recovery indicator and our NMDS dimensions of recovery. Comparing R-square values produced by vector fitting and surface fitting helps us explore whether linear or non-linear models better represent how each recovery indicator contributes to our dimensions of recovery. Specifically, we follow Nelson, McCune, Roland, and Stehn (2015) in using a 5% improvement in the variance explained (R-square) by surface fitting compared to vector fitting to identify recovery indicators exhibiting non-linear associations. In this way, our analysis ensures the recognition of non-linear dynamics, when they may exist.

Compared to linear associations, non-linear associations explained more of the co-variation between each recovery indicator and our two dimensions of recovery. For example, earthquake impacts on herding and farming differed depending on whether they were struggling to continue their shepherding and marginal farming in their villages or potentially lost all of their livestock and/or had extreme impacts to their fields and were in camps. These differences in recovery can be seen in Figs. 2 and 3, with quadrant 1 representing households that were still in their villages and quadrant 3 represents households in displacement camps. For the variable "high impacts to non-irrigated (*bari*) fields" (non-linear R^2 = 0.425; linear R^2 = 0.376) visualized in Fig. 3, the non-linear relationships occur for households in quadrants 1 and 3 in the recovery space. There were thus different types of negative recovery situations that functioned in non-linear ways. Employing surface fitting to the 34 recovery indicator variables over the two research phases, the highest non-linear R-square values were for herding and non-irrigated farming impacts; each generally exhibits a pattern where the negative recovery indicators behave in non-linear ways (see SM 5 for comparison of linear and non-linear results of the recovery indicators).

5.4. Ordination by location over time

Fig. 4 illustrates the ordination for each VDC at phase 1 and phase 2, showing each household's pattern of recovery at phase 1 and how the household's recovery changed by phase 2. We can thus use this figure to track a cluster of settlement's average position within the recovery space over time (see Table 2 for full results). To further identify specific household trends within settlements, we can separate out each settlement and place each household during phase 1 at the origin (0,0) and lines indicate whether the household increased or decreased along each dimension of recovery (Axis 1 and 2). By examining the number of lines in each quadrant, these figures can be used to identify temporal trends in patterns of recovery from phase 1 to phase 2. For example, Figs. 5 and 6 illustrate the positions of households in Aaru Chanaute (VDC 1) and Gatlang (VDC 3) within the recovery space in phases 1 and 2 (see SM 1–4 for each VDC). For the more-accessible culturally diverse Aaru Chanaute (VDC 1), households generally started in the positive recovery space and moved in more positive directions; although Figs. 4 and 5 also illustrate sparse movement for some households into the negative recovery space between the time periods. We found that inaccessible and more homogenous Kashigaun (VDC 2) had a variety of starting points in the negative and positive recovery space and that households were moving more in positive than negative directions (Fig. 4 and SM 2). Accessible NGO prevalent Gatlang (VDC 3) appears to start in both the negative and positive recovery space, but was moving almost exclusively into the negative space (Figs. 4 and 6). Inaccessible and displaced Haku (VDC 4) started predominately in the negative recovery space with the displacement camps clustering in quadrant 3 and was split in phase 2, moving in both positive and negative directions (Fig. 4 and SM 4).

The next task is to see how the recoveries of each individual VDC compares to the other VDCs. The patterns from our ordination illustrate that each VDC experienced statistically and substantively different recoveries than the other VDCs. We tested the statistical significance these differences using a non-parametric Multi Response Permutation Procedure (MRPP) (McCune & Grace, 2002). We found significant differences in recovery patterns through paired comparisons of VDCs (T = −0.91.854; A = 0.077; P = .000). Aaru Chanaute (VDC 1) and Haku (VDC 4) were the most different from all the others (T = −97.790; A = 0.103), while Kashigaun (VDC 2) and Gatlang (VDC 3) were the most similar (T = −24.067; A = 0.023). For accessibility in general, accessible and inaccessible households also differed (T = −19.295; A = 0.009; P = .000). When we grouped VDC and accessibility together differences became more apparent (T = −74.369; A = 0.089; P = .000). Here, the highest differences emerged in the comparisons for accessible households in Aaru Chanaute (VDC 1) versus accessible households in Kashigaun (VDC 2) (T = −50.313; A = 0.115), and inaccessible households in Kashigaun (VDC 2) (T = −34.856; A = 0.119), Gatlang (VDC 3) (T = −43.188; A = 0.172), and Haku (VDC 4) (T = −70.354; A = 0.120). The most similar areas were accessible households in Kashigaun (VDC 2) versus inaccessible households in Kashigaun (VDC 2) (T = −3.884; A = 0.008). The difference between households in displacement camps versus households not in camps was also significant (T = −70.205; A = 0.034; P = .000), with greater differences than accessibility.

In subsequent research, we build on the analysis of the recovery indicators in NMDS by adding demographics (e.g., ethnic group, religion, household size, literacy, education level, male versus female head of household, relocation to displacement camps, whether household took a loan for rebuilding-34 variables) and the additional domains of adaptive capacity (hazard exposure (12 variables), institutional participation (12 variables), livelihood diversity (73 variables), connectivity (16 variables), and social memory (27 variables). We employ vector and surface fitting to understand associations among recovery indicators, biophysical indicators, and mitigating household characteristics (domains of adaptive capacity) over both short-term intervals (see Spoon, Gerkey, Chhetri, Rai, & Basnet, 2020). We also compare these results with findings from qualitative research (see Spoon et al., 2020; Spoon et al., 2020).

5.5. Contextualization from research return workshops

In our multi-scale research return workshops all participants verbally affirmed these results and were complementary regarding research process and return. We presented our conclusions about the two dimensions of recovery and our interpretation of them (pattern identification plus interpretation) and they felt it echoed their own perceptions, experiences, and interpretations. Participants felt that cascading effects from earthquakes (e.g., landslides, shifted water sources, severe weather affecting temporary shelters) were making prospects for recovery worse as time passes. This perception parallels our results visualized in Figs. 4–6 where several households in all VDCs were moving into the negative recovery space (see SM 1–4 for visualizations of all VDCs). The future was considered highly uncertain. The households from the displacement camps and inundation zone shared that they had difficulty in accessing the government house reconstruction grants and that their futures were highly unclear due to the inevitably

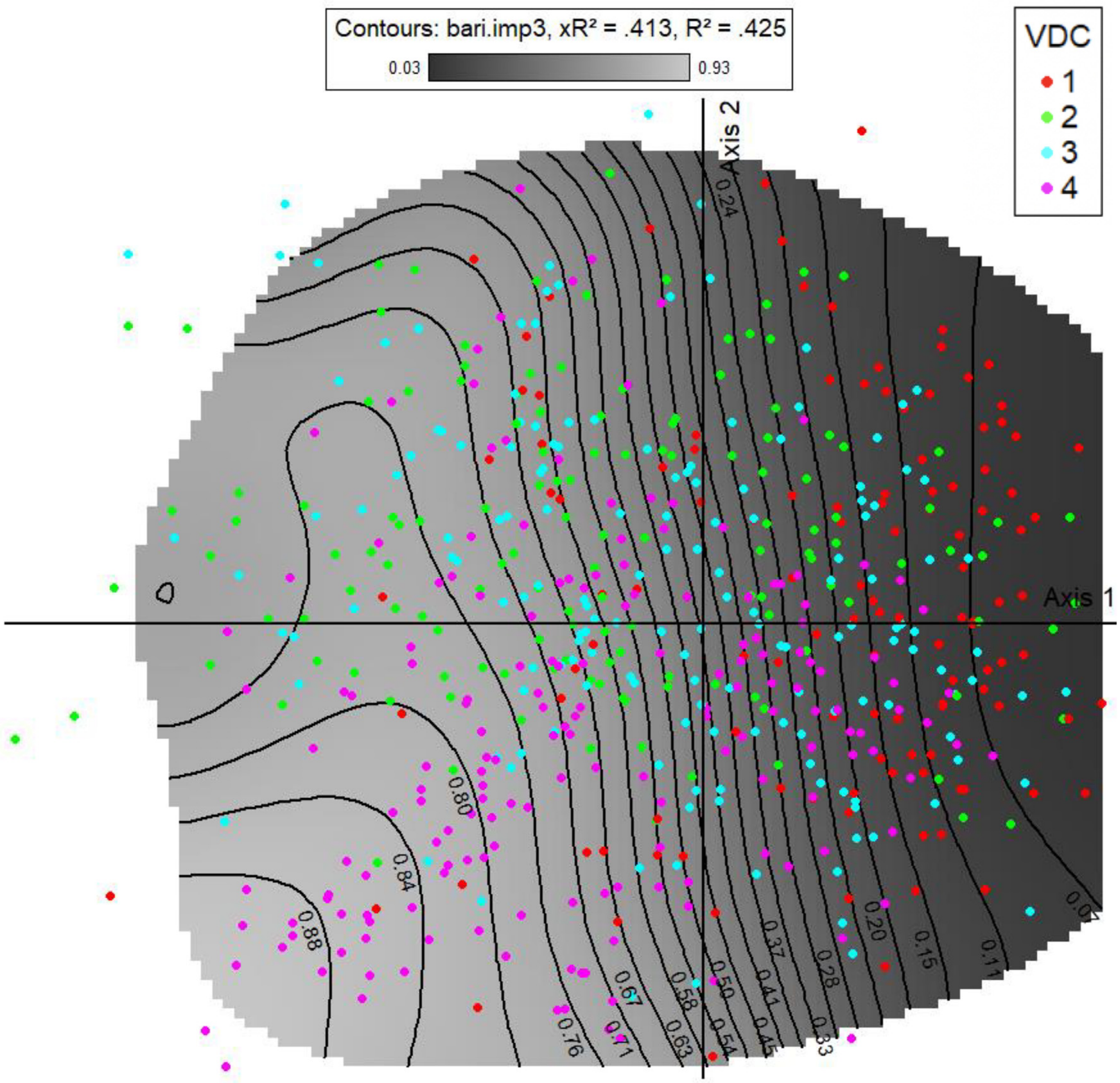

Fig. 3. Non-linear surface fitting, showing association between high earthquake impacts on non-irrigated fields and NMDS dimensions of recovery (without rotation). Notice differences in non-linear dynamics in quadrants 1 and 3 (curved lines) and linear dynamics in quadrants 2 and 4 (parallel lines). This illustrates that households in negative parts of the recovery space are experiencing different types of impacts (non-linear) on their fields depending on their degree of displacement. (VDC 1 = Aaru Chanaute; VDC 2 = Kashigaun; VDC 3 = Gatlang; VDC 4 = Haku).

of resettlement. Indeed, a displacement camp resident from Haku exclaimed "we have no idea how the government is going to relocate our settlement and how we'll get the compensation for our lands." A businessowner from Aaru Chanaute shared:

"Those who took loans from banks for business purposes or for construction of houses haven't been able to pay back neither interest nor principal. We would like the government to forgive our loans. Some people would like to start new businesses; however, they do not have money to invest as banks will not grant them loans."

All locations considered accessibility to affect the cost and transport of building materials, which in turn determines the size, safety, and quality of new rebuilt homes. The 3 lakh (~US$ 3,000) provided by the government was considered insufficient to construct houses to the new designs and building codes, forcing the construction of smaller houses than those that preceded the earthquakes often not large enough to accomodate their family members. For instance, a Gatlang resident stated "we are following the government building codes only to get the rebuilding money. Otherwise, the one room house built with the relief grant is not enough for our households and we're not satisfied with it." This perspective is illustrated in Fig. 2 (quadrant 2), where households that were able to return to their homes where still having issues rebuilding. Participants felt that the government should do more than assess damage to homes, such as helping to control future landslides, an example of a local articulation of integration social and environmental system dynamics. All locations shared that INGO/NGO assistance was not sustainable, often repeated in the same place by different organizations, and as only providing short-term relief. Indeed, a Haku government representative stated that "we've realized that [INGO/NGOs] giving relief materials is not a big deal, but, sharing the findings (of this research) from the local level to the national level is a big deal." Lastly, a Kashigaun participant shared that "every [INGO/NGO] should bring different projects and not copy each other. They should work with local authorities to know whether we really need those projects or not" (see Spoon, Gerkey, Chhetri, Rai, & Basnet, 2020; Spoon et al., 2020; Spoon et al., 2020 for further discussions on local perceptions of the government reconstruction program, outside aid, housing designs, and building codes)

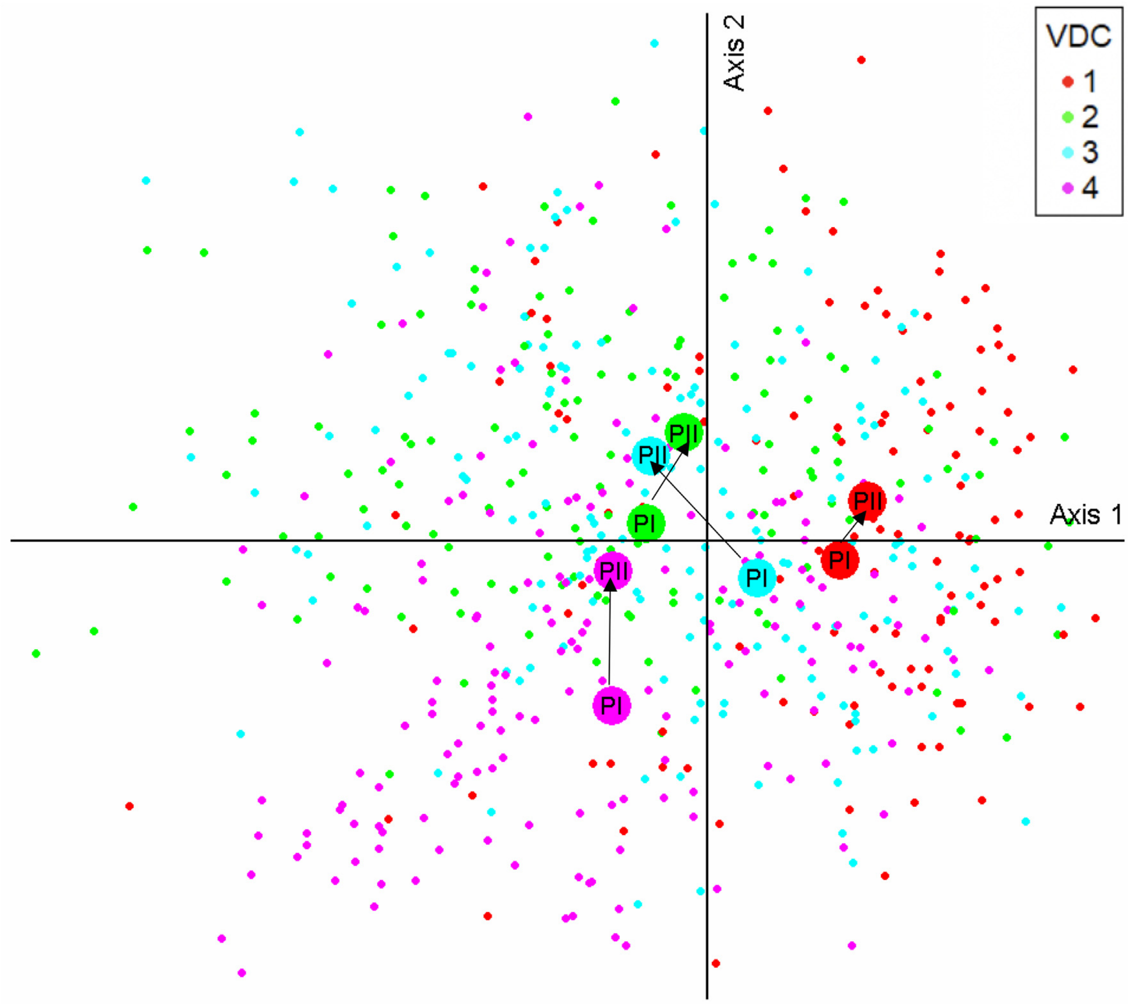

Fig. 4. NMDS scatterplot of recovery indicators for entire sample (N = 397 households) at phase 1 and phase 2 with centroid (average positions) of households in each VDC across both time periods (VDC 1 = Aaru Chanaute; VDC 2 = Kashigaun; VDC 3 = Gatlang; VDC 4 = Haku).

5.6. Study limitations

We recognize that there are issues with quantitative research and modelling in disaster zones, especially with the amount of uncertainty in these contexts (Barrios, 2016a, 2016b; Button, 2010; Faas, 2016; González & Faas, 2016); however, generalized models are often utilized by governments and aid organizations in their disaster preparedness, response, and recovery planning. These actors may find the lessons learned from critical qualitative ethnographies more difficult to operationalize in dynamic and fluid disaster contexts. Our hope is that we can provide an approach that captures some of the most important facets of recovery and that it is "less wrong" than other models, generalizable to other rural contexts but flexible enough to include the nuances specific to the studied settlements. We attempt to circumvent oversimplification by incorporating a diverse set of recovery indicators and contextualizing our findings through research return workshops. Our subsequent research also informs interpretation (Spoon, Gerkey, Chhetri, Rai, & Basnet, 2020; Spoon et al., 2020; Spoon et al., 2020).

6. Discussion

6.1. Assembling disaster recoveries: Heterogeneities of experience

Natural disaster recovery is multidimensional and heterogenous. Our findings revealed that there was wide variation in recovery experienced by households in our sample. Some households were moving in positive directions while others were travelling in negative directions at phase 2, which means that circumstances were getting better for some and worse for others. Nearly all homes and infrastructure were damaged or destroyed by the earthquakes; however, the starting points and recovery trajectories differed depending on settlement. Indeed, successful recovery appears to work differently, often unequally, for various communities (Barrios, 2016a) and requires flexibility and responsiveness towards populations (Maldonado, 2017; Zhang, 2015).

We assemble the NMDS results from our pattern identification and interpretation to understand how the entire sample and each settlement experienced recovery at the two time intervals of 9 months and 1.5 years after the earthquakes. This approach helped us identify several common patterns in recovery, despite variation across multiple indicators. First, households reliant on place-based agropastoralism were having the most challenges recovering. Second, the experiences of households in displacement camps were distinct from those not displaced. Third, accessibility was a factor in recovery, but marginally, even though this was highlighted by participants. Fourth, households in a planned dam inundation zone were stuck in a liminal sate between the time intervals waiting for relocation. Resilience to the earthquakes appeared to be tied to an assemblage of factors, both spatial and cultural. Households heading on negative trajectories appeared to be fragilely reliant on biophysically uncertain land and outside

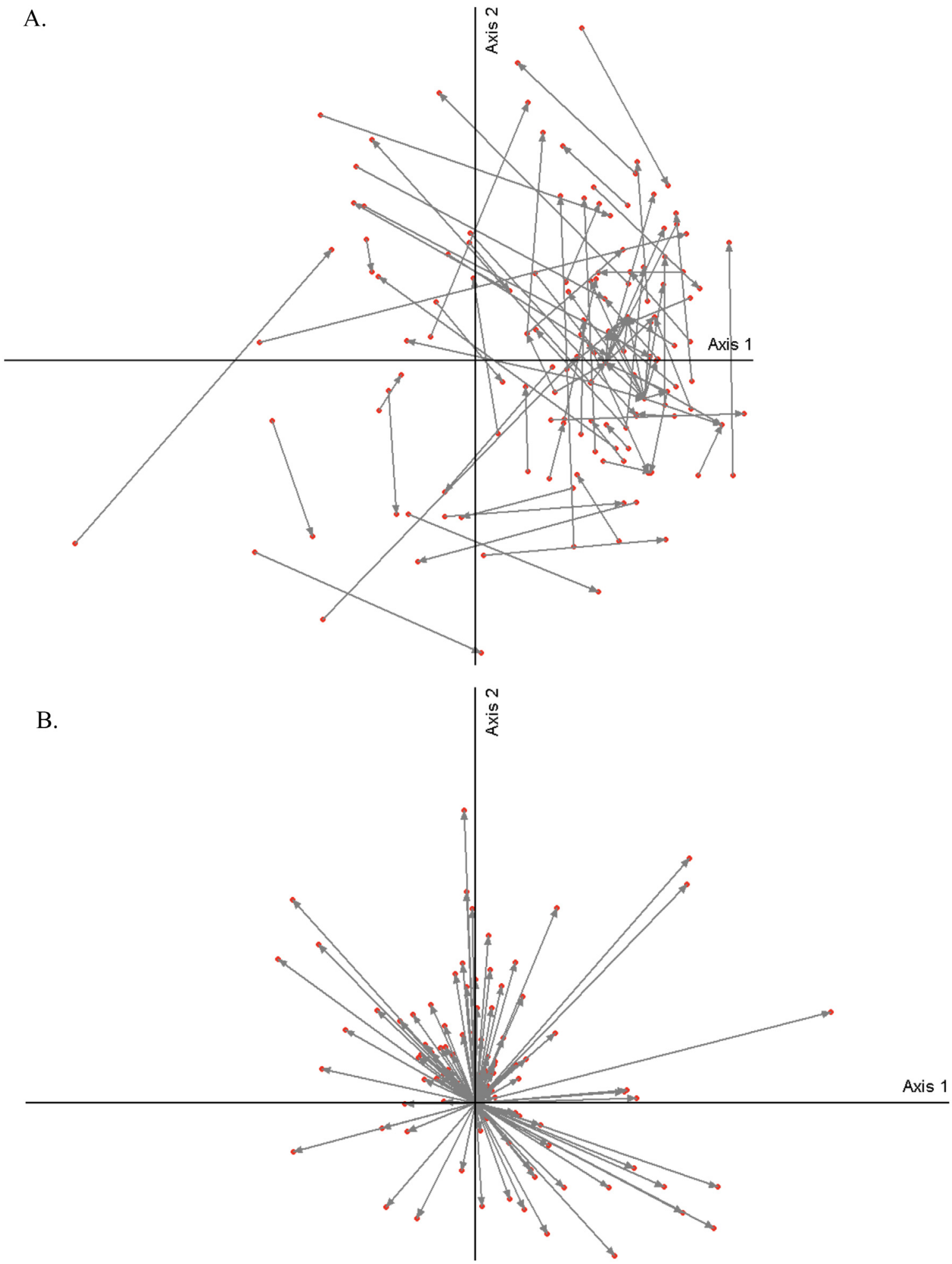

Fig. 5. NMDS scatterplot of recovery indicators for Aaru Chanaute (VDC 1) in phases 1 and 2 (A) and phase 2 (phase 1 as 0,0) (B). Note that most households start in the positive recovery space (Axis 1) and move marginally in both positive and negative directions in phase 2.

intervention. Uncertainty related to relocation from displacement camps and for hydropower development also appeared to influence recovery rate.

The thematic discussion that follows uses our NMDS results and supporting descriptive statistics as starting points to contextualize and begin to navigate the complex dynamics driving household and settlement recoveries. Where appropriate, we integrate insights from our research return workshops, participant observation, key consultant interviews, and literature. We also indicate where our additional research would add to the discussion (See Spoon, Gerkey, Chhetri, Rai, & Basnet, 2020; Spoon et al., 2020; Spoon et al., 2020).

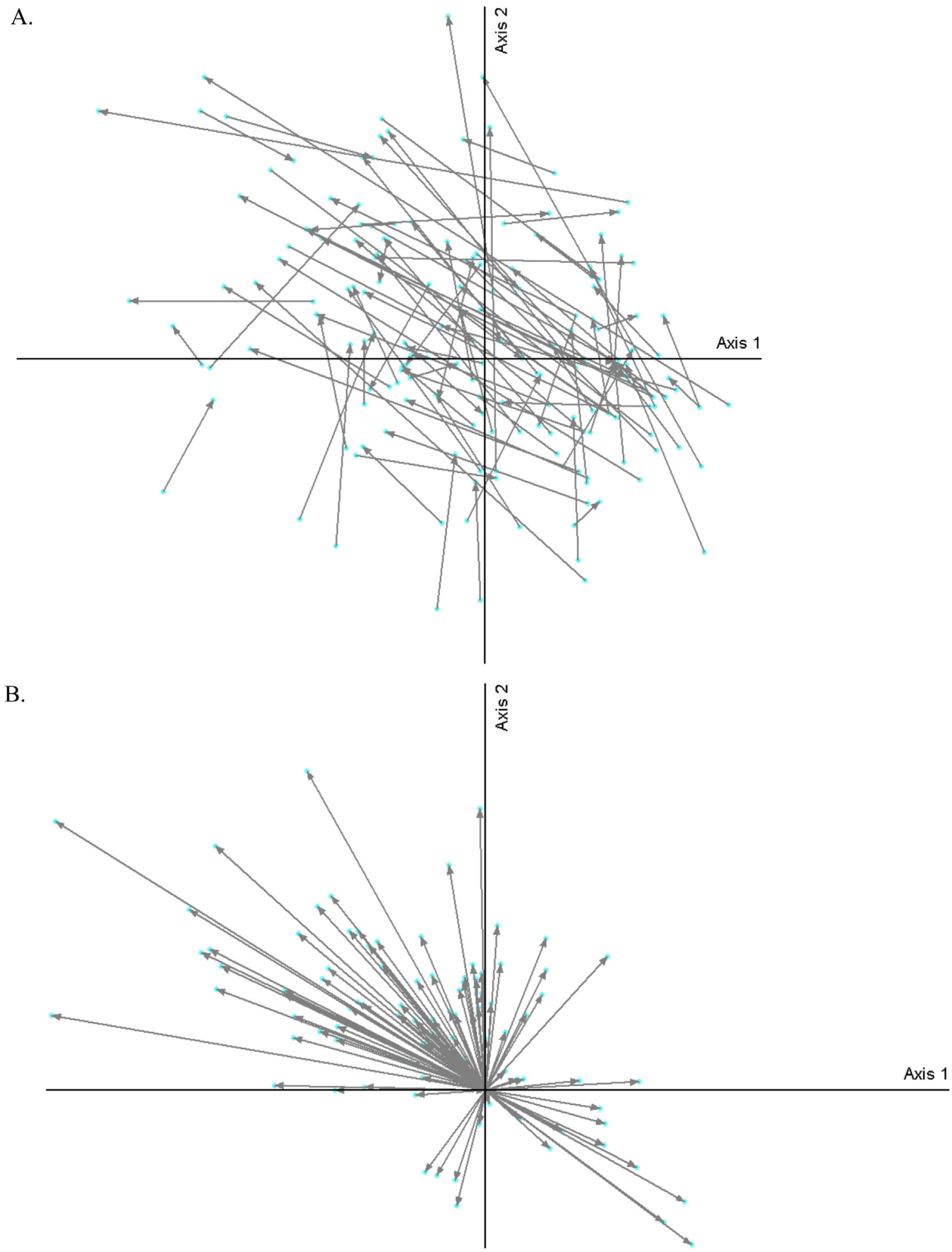

Fig. 6. NMDS scatterplot of recovery indicators for Gatlang (VDC 3) in phases 1 and 2 (A) and phase 2 (phase 1 as 0,0) (B). Note that households start in both the negative and positive recovery space (Axis 1), but move more into the negative space at phase 2.

6.2. Displacement and liminality

The NMDS ordination mapped the impacts and trajectories of households with different types of non-linear negative recovery indicators. Our surface fitting results for the recovery indicators illustrate the impacts and recovery trajectories of households in displacement camps generally differed from those not displaced. These differences were particularly apparent for livestock impacts, where households in displacement camps lost livestock; whereas, households that remained in their homes had impacts to livestock health, behavior, and productivity (see quadrants 1 and 3 in Fig. 2). Impacts to *bari* also differed on whether households were in camps (Fig. 3). In this case, households in camps had their fields catastrophically impacted by landslides, often to a point where they no longer exist. For households not in camps, their fields were also impacted by earthquake shake intensity and resulting landslides through cracks or by having them covered by landslide debris (see Spoon et al., 2020; Spoon et al., 2020). Issues for these types of fields were getting worse between the two research phases, with 53% of households reporting issues with these fields at phase 1 compared to 71% at phase 2. The differences between households in and out of camps are considerably greater than accessible versus inaccessible households. As Nepali identity is intimately connected to "territorial belonging" (Shneiderman, 2017), displacement from Indigenous homelands can have dramatic impacts on recovery. Indeed, research illustrates that place attachment connects people to place in disaster contexts (Hoffman, 2016) and can assist with recovery (Cutter, Burton, & Emrich, 2010). Research also shows that displacement into camps also leads to negative recovery outcomes (Schuller, 2012, 2015) and that temporality over the short- and long-term helps to illuminate how livelihoods change through resettlement in general outside of disaster contexts (Pigott-McKellar, Pearson, McNamara, & Nunn, 2019).

Landslides triggered by the earthquakes were the typical culprit for the devastation that forced households into temporary shelters and camps. In Haku (VDC 4), catastrophic landslides that occurred above the villages killed people and livestock, destroyed homes, covered non-irrigated agricultural fields, and killed livestock in three settlements (Fig. 1). The earthquake forced relocation of surviving households to seven different displacement camps, in which 63 out of 64 relocated households remained at phase 2. The displaced households themselves were forced to lease the land to build temporary shelters and paid the leased amounts to the landowner. At 2.5 years, two out of the seven camps still functioned, with the remaining households having returned to their villages. The biophysical vulnerability of these households appeared to increase between phase 1 and 2; at phase 1, 55% of household reported that landslides threatened their community whereas at phase 2, 88% perceived these threats, especially in Kashigaun (100%) and Haku (97%). Access to grazing areas and *bari* or non-irrigated fields also worsened between phase 1 and 2 for all VDCs except Aaru Chanaute (see Spoon, Gerkey, Chhetri, Rai, & Basnet, 2020; Spoon et al., 2020; Spoon et al., 2020 for further discussion on hazard exposure).

Some households marginally moved in the recovery space across the two research phases. This liminality or stagnation was apparent in Aaru Chanaute (VDC 1) where households in the market area are in the planned inundation zone for a 3383 GWH dam funded by the Nepal Government. The ordination over time illustrated that these households in the planned inundation zone started in the more positive recovery space and moved little or in the mostly negative directions at phase 2 (Figs. 4 and 5). This may represent the liminality brought by the proposed hydropower development; at 2.5 years after the earthquakes, the Nepal Government was yet to resettle households. Accessibility will dictate compensation for resettlement, with more accessible households (i.e., near the road or in the market area) receiving more funds. Households were thus marginally patching their homes and waiting for the resettlement program to begin.

6.3. Accessibility and aid

We expected accessibility to be a driving factor in recovery. Our results suggest a pattern with accessible households having slightly more positive recovery indicators than less accessible ones, and this result was substantively and statistically significant in the MRPP analysis. However, the differences between accessible and inaccessible households were less pronounced than for other variables, such as VDC or whether households were displaced or not. Grouping access and VDC illustrated that accessible settlements in Aaru Chanaute (VDC 1) were recovering differently than all other settlements. Accessible and inaccessible settlements in Kashigaun (VDC 2) and Gatlang (VDC 3) were the most similar. We selected the four clusters of settlements (VDCs) to represent both accessible and inaccessible areas; however, upon closer examination, settlements in each VDC exhibited variation in accessibility, depending on proximity to road, trail, or helipad. These indicators were contexts for receiving aid from various sources after the earthquakes and in the years that followed. Accessible households also had more access to aid and participation in market economies through shops and tourism.

The results for Gatlang (VDC 3) went opposite of the predicted association between access and recovery. Across the two time intervals, most households in Gatlang appeared to be heading in a negative direction. In the NMDS ordination over time, these settlements appeared to start in the more positive recovery space and headed almost exclusively into the negative space (Figs. 4 and 6). Our descriptive statistics showed that at phase 2, only 8% of households had returned to their homes from temporary shelters—by far the lowest value in the study and only comparable to households in displacement camps. We argue that our results reflect Gatlang's growing dependence on outside aid and a more tourism-centered economic logic, which are both factors reinforced by their proximity to the road. In other contexts, the combination of natural hazards and development caused a loss of social capital and social networks (Yang, Dietz, Kramer, Ouyang, & Liu, 2015). Aid interventions may prevent communities from developing relationships, skills, and cohesiveness (Paton et al., 2014) and created and exacerbated segregation, competition, and inequalities (Amarasiri de Silva, 2009). Outside interventions can also dislocate social networks (Casagrande, McIlvaine-Newsad, & Jones, 2015). In all these cases outside aid impeded recovery in some way. Indeed, poor coordination within the aid community extends beyond disaster recovery and can impede achieving more general sustainable livelihood goals (Caiado, Goyannes, Filho, Quelhas, Nascimento, & Ávila, 2018).

The two settlements of Gatlang and Gre are accessible by road, although Gatlang has more access to aid and government services. There were more NGOs and INGOs in Gatlang VDC than any of the four other locations in the study prior to, during, and after the earthquakes. It also has fairly well-developed tourism industry that benefits some, but definitely not all. The area is ethnically homogenous (Tamang); we found little evidence of operationalizing *parma* or work exchange to rebuild homes compared to other settlements. The nuclear family, rather than mutual aid networks, seemed to drive recovery decisions and actions, calling into question shifting definitions of what constitutes "community" and "family" before and after the earthquakes. Indeed, the interdependencies among social actors in the agropastoral way of life appeared to wane in this area compared to others. The Tamang and Gurung/Ghale ethnic groups also have different migration histories and experiences in Nepal in relation to the caste system, which generally considered Gurung/Ghale as higher status than Tamang (Campbell, 2013; Regmi, 1991). These power dynamics may in turn reinforce or impede communal action. Gatlang residents are also primarily herders rather than having more diversity in their livelihoods (Spoon, Gerkey, Chhetri, Rai, & Basnet, 2020).

Access in the case of Gatlang may be a "trap" where individuals receiving assistance adapted to wait for help rather than help themselves (Nelson & Finan, 2009) or that they are using their visibility for their own advantages (Parson, 2016). The road may be impeding creating more localized solutions to problems created by the earthquakes. Most households in Gatlang were moving in negative directions at phase 2; at this time, only 8% of households had returned from temporary shelters to their permanent homes. Their connections with aid organizations and markets may therefore be impeding their capacity to recover. Research indicates that the aid industry can overlook local institutions in disaster recovery, using a "one size fits all" mentality (Paton et al 2014; Barrios, 2016b). Interventions can also appropriate local practices to their own external rules and parameters (Faas, 2017). There is evidence of this in Gatlang over the short- and longer-term. The aid that was received appears to not have been enough to help the residents of Gatlang to recover to a comparable point where they were at before the earthquakes and contained generic rebuilding solutions that did not take into account local knowledge or perspectives. In our research return workshops, it was reiterated to us that the aid was not sustainable and akin to providing a "fish without a net." This translated into immediate relief but far less assistance in livelihood reconstruction. For example, immediate household assistance at phase 1 from international NGOs served 74% and national NGOs served 89%, which was exclusively relief materials such as tarps, food, blankets, and a small cash disbursement; this dropped to 17% and 4% respectively at phase 2 with varying levels of engagement across the four settlements. This trend in short-term unsustainable aid often centers around the desires of the donors (Jones, Oven, & Wisner, 2015; Zhang, 2015). It is evident in longitudinal studies elsewhere (e.g., Zhang, 2015; Doughty, 2012) and can foster disaster capitalism (Klein, 2017; Schuller & Maldonado, 2016), where national and transnational governmental and non-governmental institutions profit from reconstruction and forward neoliberal economic agendas.

6.4. Cooperation and work exchange

The results from Kashigaun (VDC 2) are an interesting contrast to Gatlang (VDC 3) described above. The ordination for Kashigaun over time found that households generally started in the more negative recovery space and were moving in *both* positive and negative directions (Fig. 4 and SM 2). At both points in time, the households operationalized work exchange to rebuild. At phase 1, the households pooled the relief funds provided by the government to provide food and basic shelter materials to all households. By phase 2, 92% of the households in our sample had returned to their homes from temporary shelters; however, few, if any, were rebuilt to code. At 2.5 years, many households were participating in the government rebuilding program and were constructing small houses so that they can access the remaining installments of rebuilding funds provided by the government (see Spoon et al., 2020) . Various studies demonstrate that social capital and social networks were important factors in disaster recovery (Aldrich, 2011; Ganapati, 2012; Vallance & Carlton, 2014), including the 1934 (Bhandari, 2014) and 2015 (Epstein, DiCarlo, Marsh, Adhikari, Paudel, Ray, & Måren, 2018) Nepal earthquakes. Social capital is also considered a critical element of the Sustainable Livelihood Framework (Sudipta et al., 2020; Silva et al., 2020; Pigott-McKellar, Pearson, McNamara, & Nunn, 2019).

Kashigaun is two to three day walk from the road and is somewhat ethnically homogenous (primarily Gurung/Ghale). There were few NGO and INGOs and some Christian missionaries serving the area. The fact that there is historically less of an aid presence and market presence in Kashigaun coupled with their utilization of *parma* may help to explain why they have been able to adapt the way that they have. Their distance from the road head may also stimulate communal action for creative problem solving. This is especially noteworthy considering the amount of biophysical vulnerability experienced by them due to their proximity to landslides (Fig. 1), which was extremely high and part of everyday life; at phase 2, 100% of the households stated that landslides threatened their settlements. In our research return workshops, key consultants from Kashigaun shared that the earthquakes helped to revive and reinforce the local *parma* tradition, especially as a safety net for the poorest and most marginal households.

6.5. Resilience and potential transformations in everyday life

The resilience of these households to the earthquakes or their ability to recover is a result of many factors. Our NMDS ordination showed over time that although 99% of homes and 100% of infrastructure were critically damaged or destroyed in our sample, households started and were travelling in different recovery trajectories. The households that appeared the most resilient to the earthquakes at phase 1 were those that had less agropastoral-based livelihoods, more market connections, and easier access to rebuilding funds from the government and through loans, such as many households from Aaru Chanaute (VDC 1) (Figs. 4 and 5); the households that were travelling in more positive directions at phase 2 may have operationalized social capital, such as work exchange, to recover, such as households from Kashigaun (VDC 2) (Fig. 4 and SM 2). Indeed, cooperation assisted with recovery in another highly impacted district from the Nepal earthquakes (Epstein et al., 2018).

The households that appeared to change in the negative direction the most between phases 1 and 2 were those from Gatlang (VDC 3), although some households in each location travelled into the negative recovery space at phase 2 (Figs. 4 and 6). These rapid shifts during a six-month interval after the earthquakes (between 9 months and 1.5 years) could suggest a nascent transformation in everyday life. There may also be further evidence of transformation for households from Haku (VDC 4) who were displaced from their homes into camps, stagnant for almost 2 years, and mostly returned to their villages by 2.5 years (Fig. 4 and SM 4). In 2018, the Nepal Government also resettled one community (Sano Haku) one day walk from the original location due to landslide vulnerability. Additional evidence may also exist for households in the inundation zone of the dam in Aaru Chanaute. Future research will follow these households over a broader temporal scale to view whether or not these trends illustrate evidence of these transitions over time.

7. Conclusion

The 2015 Nepal earthquakes caused catastrophic damage to life and property. Its effects have been felt by survivors for years afterward. Recovery is heterogenous depending on location and impacts. First, households dependent on place-based agropastoral livelihoods had the most challenges recovering compared to households with more diverse market-based livelihoods. Second, the experiences of households in displacement camps were different from non-displaced households. Third, accessibility determined recovery outcomes but not in a consistent or strong way. Fourth, households in the planned inundation zone of a dam were stuck in a liminal state, unable to rebuild and waiting to be relocated. At 2.5 years after the earthquakes, research participants and key consultants validated these results and added contextualization in a series of local and national research return workshops. We deduce from our results that aid may be negatively or marginally benefitting recovery. Some households did operationalize social capital through cooperation to assist with recovery in the short-term after the events; others did not appear to assist one another and instead were waiting for additional support from outside. Our study contributes to the literature on disaster recovery and development aid in four ways: First, we provide a unique dataset with a random sample of 400 households over two time intervals collected immediately following a catastrophic natural disaster. Second, our methodology documents and analyzes recovery as a multidimensional phenomenon with more than 30 recovery indicators. Third, our study empirically illustrates linear and non-linear dynamics, which are often theorized but not empirically demonstrated. Fourth, we developed a method that captures the complexity of variation at the household and settlement levels but also identifies patterns that resonate on the ground. Our results have relevance to local communities, governments, and development agencies in Nepal and elsewhere to better understand the factors that contribute to resilience and change in rural natural disaster recovery.

The lessons learned can help to evaluate relief and reconstruction interventions where expert knowledge (Barrios, 2016b) ignores cultural and spatial diversity, such as the roles of local knowledge and institutions (Audefroy, 2011; Bohensky & Maru, 2011; Kenney & Phibbs, 2015). Governments and the aid industry can also use them to facilitate multi and polyvocality (Barrios, 2016a) and foster linkages among local–global actors (Kilby, 2007). Contextualizing impacts and recovery trajectories can also contribute to crisis (Kapucu & Demiroz, 2017) or transformative learning (Sharpe, 2016), which builds upon resilience to inform decision making, such as appropriately integrating work exchange into recovery programs or scaling programs to market access that consider inflation due to geographic marginality. Mapping recovery using multidimensional variables can thus help to navigate how rural mountain communities and others recover from extreme disturbances, such as an earthquake and its cascading effects, over time and some of the drivers of these outcomes leading to improved response and longer-term planning.

CRediT authorship contribution statement

Jeremy Spoon: Conceptualization, Methodology, Formal analysis, Investigation, Writing-original draft, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Drew Gerkey:** Conceptualization, Methodology, Formal analysis, Writing-original draft, Writing - review & editing, Visualization. **Ram Bahadur Chhetri:** Conceptualization, Methodology, Writing - review & editing. **Alisa Rai:** Methodology, Investigation, Writing - review & editing, Supervision, Project administration. **Umesh Basnet:** Methodology, Investigation, Writing - review & editing, Supervision, Project administration.

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

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