Livelihood diversification, mobile phones and information diversity in Northern Tanzania

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ABSTRACT

Throughout the developing world, households are diversifying their livelihood activities to manage risk and improve their lives. Many studies have focused on the material causes and consequences of this diversification. Few, however, have examined how diversifying groups establish new patterns of communication and information exchange with others. This paper examines the relationship between livelihood diversification and information diversity among agro-pastoralist Maasai in northern Tanzania, where new mobile phone use is common. Mixed qualitative and quantitative methods of data collection and analysis are used to (1) describe how Maasai use phones to manage diverse livelihoods; and (2) assess the relationship between livelihood diversification and measures of information diversity, controlling for other factors. The findings indicate that households use phones in ways that support existing activities rather than transform them and that the relationship between livelihood diversification and information diversity is positive, non-linear, and significant.

1. Introduction

A longstanding concern within the scholarship on land-use change is livelihood diversification (LD) by smallholder agricultural and pastoralist groups in rural areas (Ellis, 2000b; Barrett et al., 2001). With LD, households and communities pursue diverse economic strategies to manage uncertainty and improve their lives. Much of the research on LD has focused on its material causes and consequences. Implicit in these studies, however, is the notion that as people engage new economic activities, they come into contact with new groups of people – and new types of information.

Information is a critical resource. It is a key form of social capital, a bulwark against uncertainty, and the foundation of decision-making. And as with other resources, access to information varies. Generally, people acquire and evaluate information through their personal experiences and their social networks. For decades, sociologists and business scholars have studied the relationships between social networks, information, and economic outcomes. Studies have found that diverse networks produce diverse information – and that diverse networks and information are associated with a wide range of positive outcomes from wages and productivity to political success and innovation (Aral and Alstyne, 2011; Page, 2008; Granovetter, 1983; Bruggeman, 2016). Despite these observations from the developed world, we are aware of no studies that directly examine the relationship between LD and information diversity (ID) in developing contexts. This is especially conspicuous given the ubiquity of information and communication technologies (ICTs), especially mobile phones, throughout the developing world (Itu, 2013).

Mobile phones, now widespread throughout Africa, have been heralded as transformative new tools for social networking and economic development (Clinton, 2012). However, phone adoption has occurred within contexts where deeply engrained social, cultural and economic norms are resilient leading some to question whether new mobile technologies are merely supportive rather than transformative (Donner and Escobari, 2010; Butt, 2014). From this perspective, it may not be that phone use drives land use – but that land use drives phone use.

With this paper, we seek to contribute to the scholarship on rural, pastoralist livelihoods and land use by examining the relationship between LD and ID in an area where mobile phones are becoming commonplace. Here, LD is an *established* mechanism by which rural households become variably connected with new groups and new types of information. Alternatively, mobile phones are important *new* tools to facilitate communication. Following this approach, we use mixed methods to examine how mobile phone-use has been incorporated into diversified pastoralist livelihoods and how LD is associated with diverse modes and types of communication and information exchange. To address these concerns, we focus on four ethnically Maasai, agro-

pastoralist communities in northern Tanzania where phone use is widespread and indigenous land use faces many challenges.

2. Background

2.1. Conceptual framework

Here we present a conceptual framework that views: (1) information as a key social and economic resource; (2) the distribution of information as a function of social networks and technology; (3) livelihoods as key drivers of social networks; and (4) mobile phones as new technologies to expand and leverage networks and provide access to more types and greater amounts of information, which we refer to as ID.

Within this framework, ongoing LD is viewed as a strategy to promote economic stability by reducing income variance and managing risk individually. One consequence of this strategy is that, by diversifying into alternate economic activities, households are often in need of new types of information, which may not be readily available within their immediate social networks. As a result, households may reach out to new individuals and groups to acquire new types of information. However, in rural, developing communities, there may be many communication barriers. Mobile phones can dramatically reduce these barriers and stimulate new relationships and/or strengthen existing ones. In turn, new information procured in a timely manner, may reduce uncertainty and/or boost the returns to various investments. As described, this conceptualization points to two general research questions:

RQ1. How have Maasai incorporated mobile phones into their diversified livelihoods?

RQ2. For phone users, what are the effects of LD on ID, controlling for other factors?

2.2. Literature

These questions point to two broad areas of research within the contexts of pastoralists and smallholders: (1) livelihood diversification, (2) communication, information diffusion and mobile phones.

2.2.1. Livelihood diversification

For some developing communities, an ongoing issue has been LD. Ellis defines LD as "the process by which rural families construct a diverse portfolio of activities and social support capabilities in order to survive and to improve their standards of living" (1998, 4). Relatedly, LD is viewed as a form of risk management, often to reduce income variability (Baird and Leslie, 2013). Much of the early scholarship on LD examined its antecedents (Ellis, 2000a; Alobo Loison, 2015). These types of studies have generally focused on push and pull factors (Barrett et al., 2001), including recent attention to environmental factors (Bhatta et al., 2015; Weldegebriel and Prowse, 2013; Mccord et al., 2015; Goulden et al., 2013). These trends, which characterize much of the LD research in agricultural contexts, are also evident in the scholarship on pastoralists and agro-pastoralists (Bollig et al., 2013; Galvin, 2009). In these contexts, studies have identified several drivers of LD, including neo-liberal factors like market integration (Little, 2003), land privatization (Homewood, 2004; Galaty, 1994) and NGO-led development (Igoe, 2003). Other factors like education (Berhanu et al., 2007) and biodiversity conservation (Baird and Leslie, 2013; Homewood et al., 2009) have also been linked to diversification.

Fewer studies have focused on the consequences of LD (Bezu et al., 2011; Bigsten and Tengstam, 2011; Caviglia-Harris and Sills, 2005). Generally, studies of smallholders and pastoralists have found it to have a positive effect on measures of welfare including income, wealth, consumption and nutrition (Alobo Loison, 2015; Gautam and Andersen, 2016; Dzanku, 2015; Liao et al., 2015). Other studies have identified connections between LD and family size (Hampshire and Randall, 2000), cultural identity (McCabe et al., 2010), social connectedness

(Cassidy and Barnes, 2012), material reciprocity (Baird and Gray, 2014) and environmental change and degradation (Zimmerer and Vanek, 2016; Hao et al., 2015; Ribeiro Palacios et al., 2013). One area that has been under-explored is the effect of LD on patterns of communication and information exchange. This is an important oversight given that LD can lead individuals and groups to engage new activities, new markets, and new ideas.

2.2.2. Communication, information diffusion and mobile phones

Generally, research on issues of communication and information diffusion in rural, developing areas has been narrowly focused. Studies have tended to examine the drivers and outcomes associated with agricultural technology adoption (Doss, 2006). Research in this tradition has recently focused on the effects of social and economic networks on information flows (Van Den Broeck and Dercon, 2011; Sseguya et al., 2012; Rotberg, 2013). Scholars have also begun to examine the role of ICTs as drivers of diffusion and adoption (Mtega and Msungu, 2013; Martin and Abbott, 2011; Aker, 2011).

Indeed, the rapid growth of mobile phones in developing areas has spurred a wave of research on ICTs (Donner, 2008). Studies on phones especially have identified numerous ways in which they are promoting communication and reducing barriers to information, often in urban areas.

Mobile phone coverage has been associated with political violence in Africa suggesting that phones help political groupsovercome collective action challenges (Pierskalla and Hollenbach, 2013). Twitter use has been linked more broadly to political participation online and offline (Hopke et al., 2016). In Uganda, mobile money applications have been associated with higher remittances and household consumption (Munyegera and Matsumoto, 2016). And in Kenya, mobile layaway applications have boosted savings for agricultural capital expenses (Omwansa et al., 2013). Hampshire et al. (2015) have documented how young people in Ghana, Malawi and South Africa are using phones in various creative ways to improve access to healthcare. Also in Uganda, the expansion of mobile signal in rural agricultural areas was linked to greater sales of perishable crops (Muto and Yamano, 2009). Martin and Abbot (2011) have described mobile-phone use for women and men in Uganda, showing that adoption occurs for a limited number of key tasks but uses proliferate under varying circumstances. Alternatively, in Kenya, researchers have found that mismatches between the design of an information-sharing application and smallholders' perceptions of phone capabilities undermined adoption (Wyche and Steinfield, 2015).

Very few empirical studies of mobile phones have been conducted among pastoralist groups, a gap that others have noted (Debsu et al., 2016; Butt, 2014). These few studies have tended to focus on specific aspects of pastoralist life including access to technology, interactions with wildlife, and livestock herding and trading. In Tanzania, Msuya and Annake (2013) described patterns of technology access and use among Maasai to identify opportunities for improvement and further development. Also in Tanzania, Lewis et al. (2016) described how phones help Maasai to manage human-wildlife conflict by facilitating information exchange, coordinating group efforts and expediting emergency responses. In Kenya, Butt (2014) compared phone use across types of Maasai herders and types of information, finding that phones can both support and distract herders. Debsu et al. (2016) examined how herders and traders in Ethiopia have used phones to connect. They found high levels of inequality in access to phones and infrastructure, the effects of which were dampened by phone sharing. Research on Fulani pastoralists in Benin (Djohy et al., 2017) has found that mobile phones have stimulated new forms of social connectedness but that economic impacts have been limited. And in Kenya, despite widespread phone use among Samburu pastoralists, Asaka and Smucker (2016) found that phones were not widely used during drought periods. In this context, potential opportunities to use phones to expand social networks, procure information, and manage mobility, were outweighed by the high stakes associated with movements during drought and mistrust

of potential informants. Taken together, these studies offer support for a larger narrative within the scholarship on mobile phones in pastoralist contexts: that new technologies, rather than transforming socio-economic systems, become embedded in them.

Some scholars have questioned whether phones have been truly transformative (Carmody, 2013; Donner and Escobari, 2010), and whether existing approaches to studying ICTs have been limiting (Duncombe, 2014). Along these lines, a general concern is that phones are supporting existing activities and patterns of communication, but not stimulating new connections. This raises the question of how phones are being used in settings where existing activities themselves are in flux (e.g., LD).

Relatedly, much of this research, especially in the area of technology adoption, has implicitly characterized "information" in homogeneous ways (Kabunga et al., 2012). Fewer studies have examined how groups can have different access to diverse types of information and information flow. This may be consequential as research in developed areas has shown that access to diverse groups and types of information is associated with economic advancement (Page, 2008; Bruggeman, 2016; Burt, 2009). This is often referred to as the strength of weak ties (SWT) hypothesis (Granovetter, 1983), which focuses on differences within and across social networks and the types of social capital they proffer. From this perspective, heterogeneous, or "bridged", social networks provide access to more diverse information (and opportunities) than homogenous, or "bonded," networks (Patulny and Lind Haase Svendsen, 2007).

Some lines of inquiry have begun to examine ID in the developing world more directly. Recent studies have focused on the effect of informal associations on experimentation and social innovation (Rodima-Taylor, 2012), the effect of diverse information sources on agricultural conservation practices (Garbach et al., 2012) and smallholder wellbeing (Spielman et al., 2011), the effect of network characteristics on information sharing and reciprocity (Turner et al., 2014), the consequences of low and high quality information (Sseguya et al., 2012), and heterogeneity in exposure to information (Kabunga et al., 2012).

2.3. Study site

Over many years, Maasai have labored to realize the benefit of diversified livelihoods. They have faced political (Nelson et al., 2007; Davis, 2011; Campbell et al., 2000), environmental (Nelson et al., 2010) and technical (Homewood et al., 2009) barriers to agricultural production. They have built new networks in urban and mining areas (McCabe et al., 2014; Smith, 2015) and with agricultural groups and international organizations (Baird, 2014). Alongside these efforts, Maasai have also worked to preserve their pastoralist heritage amidst persistent and developing challenges (Miller et al., 2014; McCabe et al., 2010; Goldman and Riosmena, 2013; Galaty, 2013).

This study was conducted in the predominantly Maasai district of Simanjiro in northern Tanzania. This area of Maasailand has been the site of many studies on the tensions between conservation and local communities (Goldman, 2003; Brockington, 2002; McCabe, 1992), especially near Tarangire National Park (TNP) and the adjacent Loki-sale Game Controlled Area, which lie on the western border of the district (see Fig. 1).

Simanjiro District is well suited to investigate the relationship between livelihoods and information within a context of widespread mobile phone use. First, this rural district is predominantly ethnically Maasai (Mackenzie et al., 2014), which helps to minimize variability along cultural lines. Second, households have steadily, though variably, incorporated agriculture, off-farm employment and other small-scale economic activities into their traditional pastoralist livelihoods over many years (McCabe et al., 2014; Baird and Leslie, 2013). Also, improvements to road infrastructure and bus service have supported increased transportation between rural and urban areas. Third, people throughout this area have rapidly adopted mobile phones in the past

decade despite patchy mobile signal (Lewis et al., 2016).

A fourth argument for the suitability of this study site relates to Maasai social networks. During the colonial period, Maasai strongly resisted efforts by administrators to be settled, educated and brought within the fold of a broader, contemporary society (Hodgson, 2004). And while Maasai have embraced many types of development since Tanzanian independence, in part due to their interactions with religious missions (Baird, 2015) and protected areas (Baird, 2014) they have also maintained their traditions of polygyny, age-set social organization, and pastoralism – often in sparsely populated rural areas. Consequently, compared to many other groups in modern Africa, the Maasai have more homogenous, tightly bonded social networks wherein individuals within a network are likely to know each other, be similar to each other, and possess similar types of information (Borgatti et al., 2009; Patulny and Lind Haase Svendsen, 2007).

In this area and in other parts of Maasailand, many studies have examined the causes and consequences of LD (Homewood et al., 2009; McCabe et al., 2010, 2014; Baird and Gray, 2014; Baird and Leslie, 2013; Leslie and Mccabe, 2013). Recently, a few studies have addressed Maasai use of mobile phones (Butt, 2014; Lewis et al., 2016; Msuya and Annake, 2013). We are aware of no studies that examine the relationship between LD and patterns of communication and information.

3. Methods

Multiple methods of data collection and analysis were integrated to address each research question. The primary methodological approaches used were semi-structured group interviews and a structured survey of households.

3.1. Data collection

To examine how Maasai have incorporated mobile phones into their diversified livelihoods (RQ1), we conducted semi-structured group interviews (n = 14) with community members and leaders in four study communities to: (1) assess the ways in which phones are used in Maasai livelihoods, (2) identify the new opportunities and challenges that phones create; and (3) inform the development of a household survey instrument to estimate the incidence of communication types, including phone-based and face-to-face communications. This method allowed for open discussion around broadly framed questions about livelihood activities and phone uses as well as more targeted questions about the quality of mobile-phone signal in various areas. In multiple sub-villages in each study community, trained Maasai assistants recruited and selected group participants from a range of socio-economic backgrounds. In addition, participants were selected for their regular participation in important economic activities (i.e., agriculture, pastoralism, mining, etc.) and knowledge of current and/or historical means of communication. The interviews solicited information on a range of topics including: general phone use characteristics (e.g., calling vs. texting, use volume, age-set differences), types of communication partners (e.g., Maasai, non-Maasai, health professionals, extension specialists, etc.), types of information exchanged, use of phone functions and applications (e.g., calculator, light, calendar, radio, email, social networking, banking, etc.); phone uses for economic activities (esp. herding and agriculture), history of phones in the area, cellular tower infrastructure, and problems/concerns associated with phone use. Questions were open ended, which yielded information on many topics associated with phone use including issues directly and indirectly related to livelihoods. All group interviews were conducted by one or both of the authors with help from one or two Maasai assistants/translators.

To collect quantitative data on the incidence of communication and information types, we conducted a structured household survey in four study communities (see Fig. 1) with household heads who own and use mobile phones (n = 108). Each survey respondent was presented a list of types of people (i.e., communication partners) and types of
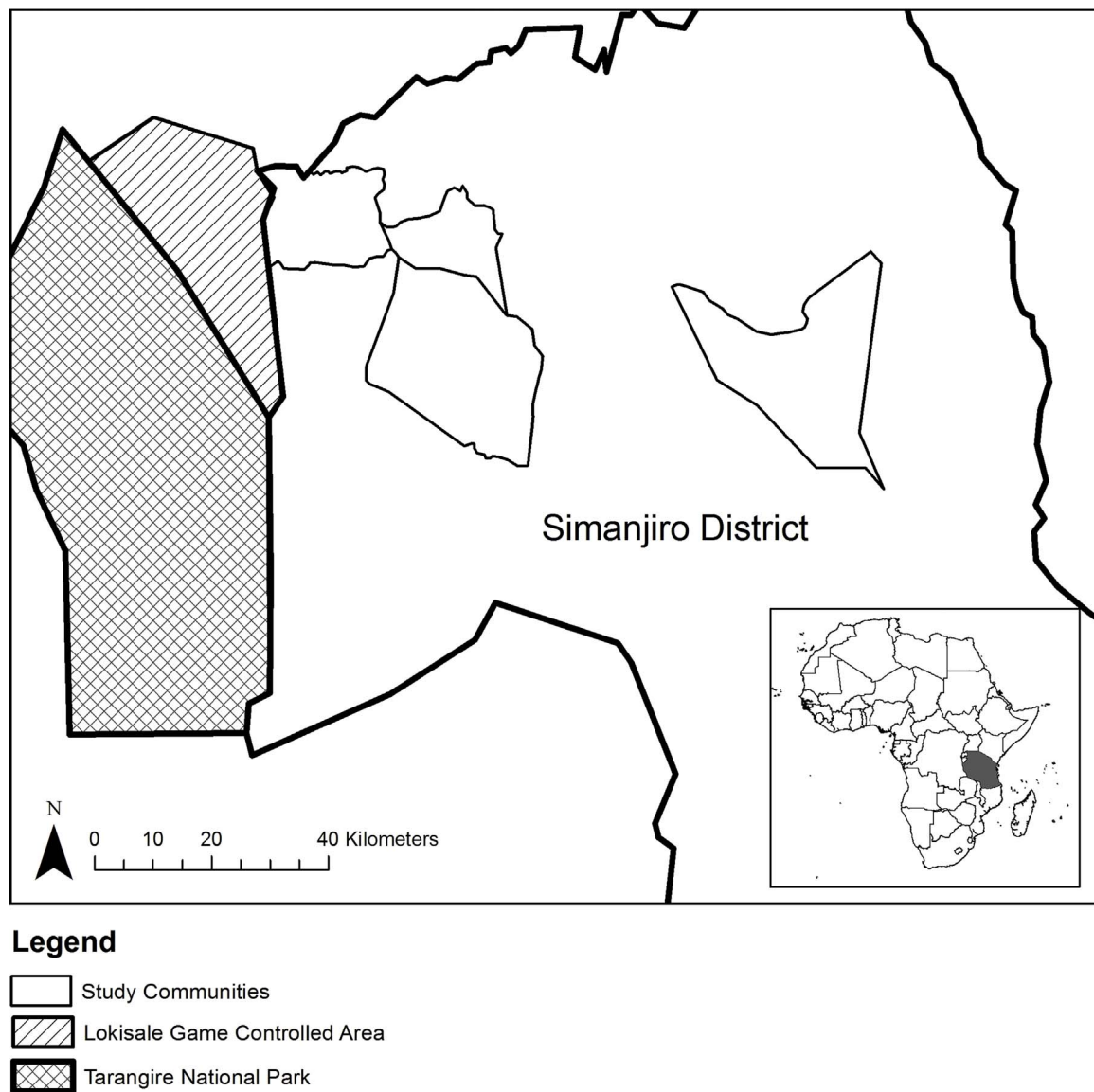
Fig. 1. Map of study areas in Simanjiro District, Northern Tanzania.

information, which were identified during group interviews. Table 1 presents these types. For each type, respondents were asked when the most recent communication occurred: within the past 24 hours, within the past 7 days, within the past 4 weeks, more than 4 weeks or never. Data were collected for both phone-based and face-to-face modes of communication for each type listed in Table 1. These measures serve as proxies for ID (i.e., number and relative abundance of types). The survey also collected data on several measures of phone use and basic household demographic and economic variables.

Without a reliable census of the district on which to base a strictly random sample, we surveyed respondents who have been part of an ongoing study of land-use in the region (McCabe et al., 2014; Baird et al., 2009). This sample, which was established in 2005 and has been added to intermittently, is based on a quota sampling strategy (Bernard, 2006) to create a representative sample. Local leaders have helped to identify: (1) households from different administrative units (in proportion to the size of the unit); (2) household heads from each Maasai age-set; and (3) households representing a spectrum of wealth statuses (proportional to local distributions of wealth). Here, herd size is used as an observable and reliable indicator of wealth. Trained Maasai enumerators conducted the survey with household heads between August and November 2014. "Households" include a household head and his/

her *dependents*, which may include multiple wives (in the case of male heads) and their children, grandchildren, parents, and siblings and even non-relatives residing with the family (Homewood et al., 2009).

Survey data provide detailed information about the respondent including his household, his livelihood strategies, and his phone uses. They also provide broad information about the types of people the respondent communicates with, the types of information he has access to, and the relative frequency of each for phone-based communications and face-to-face communications. These data, however, do not provide identifying information for the respondent's communication partners. This was a matter both of necessity and intention. First, respondents can be reluctant to reveal detailed information about the parties with whom they communicate. Second, we are broadly interested in household heads' access to diverse types of people and information rather than specific individuals and topics.

3.2. Data analysis

Our analysis of LD and ID proceeded in several steps as described below. The first set of qualitative analyses describes the primary types of phone-based information exchange (i.e., communication) and how these have been incorporated into people's livelihoods (RQ1). The

Table 1
Person and information types.

Person type[a]	Information type[a]
Tribe	Livestock
1. Maasai	1. Location of forage
2. Arusha	2. Location of water
3. Chagga	3. Market (i.e., prices)
4. Other	4. Problem with herder
Age-set	5. Problem with livestock
5. Nyangulo	Agriculture
6. Korianga	6. Markets (i.e., prices)
7. Landis	7. Non-Maasai laborers
8. Makaa	8. Female laborers
9. Seuri or older	9. Tractor hire
Women	10. Hybrid seeds
10. Mother	Work
11. Wife	11. Work in Arusha
Workers	12. Work in Mererani
12. Herder	13. Leasing land
13. Livestock broker	Community
14. Agricultural expert	14. Help for sick person
15. Veterinarian	15. Arrange IHE
16. Doctor or nurse	16. Arrange meeting
17. Government official	
18. Laigwanani	
19. Mwenyekiti	
20. Religious official	
21. Laibon	
22. Phone expert	

[a] For each type, survey respondents were asked to indicate whether they had communicated with a person type or about an information type in the past 24 hours, 7 days, 4 weeks, more than 4 weeks, or never. These responses were solicited for both phone-based and face-to-face forms of communication.

second set of analyses use regression models to understand how LD is associated with measures of communication that, taken together, can survey as a proxy for ID (RQ2).

3.2.1. Description of phone use and livelihoods

We conducted content analysis of group-interview responses to describe how phone use was incorporated into livelihoods. Specifically, we inductively coded twelve responses using qualitative analytical software (Atlas.ti). These interviews focused exclusively on mobile phone use. Beyond identifying basic uses, coding focused on connecting phone-based communication to larger social and economic processes such as household demographics (incl. family creation and growth) and herd management and development – issues that are closely intertwined. Our interpretation of these interview responses was supported by insights gained through other group interviews that focused on different aspects of Maasai society including, human well-being and human-wildlife conflict.

3.2.2. Regression models (incl. table of model variables)

We estimated eight Poisson regression models to examine the association between LD and measures of ID (RQ2). Table 2 provides a description and mean statistics for each variable included in these models. We created eight dependent variables, which together serve as a proxy for ID. These variables are divided into two strata: phone-based communication and face-to-face communication. Each stratum is further divided into two categories: communication with types of people and communication about types of information. The final dependent variables represent counts within each set of strata within a given time period. We chose two time periods: within the past 7 days and within the past 4 weeks. Correspondingly, one example of a dependent variable is the number of types of people (see Table 1) the respondent communicated with via phone over the 7 days prior to the survey. Another example is the number of types of information the respondent communicated about with someone else face-to-face in the 4 weeks prior to the survey.

We used a Herfindahl index (Rhoades, 1993) as a measure of LD. This index measures concentration, or the inverse of diversification. It is calculated as the sum of the squared percentage of income per source of total household income. Sources of income include income from livestock, agriculture, petty trade, wage labor, small business activities, mining, and proceeds from leased land. For each model, we also estimated a second specification that included a squared term of LD to test for non-linearity.

The regression models also included several independent variables to control for other factors that may contribute to patterns of communication. Household demographic measures included categorical measures of the age and education level of the household head and a continuous measure of the total number of people living in the household. Economic measures included Tropical Livestock Units (TLUs) (a common measure of wealth among pastoralist groups), total household land allocation, and total household income in the 12 months prior to the survey. These measures, which are common covariates for research on Maasai communities, represent factors that may affect the number of types of information and communication partners that respondents may engage. For example, herd or land allocation sizes may affect the number and type of people a household communicates with (e.g., workers, extension agents, government officials, etc.). Managing larger enterprises may require more or different types of communication. Alternatively, poorer households may need to reach out more for assistance. Similarly, the household head's age, education level, and family size may also shape communication patterns. Given the importance of Simanjiro's position adjacent to TNP and the connections between TNP and livelihood diversification (Baird and Leslie, 2013) and local development (Baird, 2014), we also included a measure of proximity to TNP. Lastly, each model is adjusted for clustering at the level of the community (Angeles et al., 2005), which corrects for any community-level correlation.

3.2.3. Strengths and weaknesses of approach

This study design has several strengths. First, the mixed-methods approach to data collection and analysis allowed us to integrate detailed qualitative accounts of phone-use practices across a broad range of Maasai activities with exploratory quantitative assessment of the relationship between LD and communication patterns for phone users, controlling for other factors. This study therefore contributes to the literature on pastoralist use of mobile technologies and on the social consequences of LD in the developing world. Second, this study builds the case that LD begets other types of diversity. Third, this study draws on several measures of communication, including phone-based and face-to-face, for several types of information and communication partners across a range of time periods.

The central weaknesses of this approach, which relate primarily to the quantitative components of the study, are that the sample size is small, the sampling strategy was not random, and the analyses do not include household heads without phones, and do not include women. First, despite the small sample we're confident that our mixed-methods design helps us to understand larger relationships. Second, while our sample was not random, mean measures of livestock holdings from this sample in 2010 (Baird and Leslie, 2013) are quite similar to measures from other studies of Maasai in Tanzania that used stratified random sampling strategies (Homewood et al., 2009), suggesting that this sample is not necessarily skewed in terms of livestock-based wealth. Third, this study focuses on the relationship between LD and information in an era of widespread phone use. Qualitative group interviews with community members revealed that nearly everyone now has a phone including most women and even herding-age boys from all income levels. We learned, however, that some old men do not have phones. One reason for this appears to be that these older men rely on others, including their sons and wives who do have phones, to oversee the activities of the household and the boma (i.e., fenced enclosure of multiple households). While these household heads do not own phones

Table 2
Description and means variables used in regression analyses.

Variable	Description	Means			High vs Low LD[c]
		Full sample	High LD[a,b]	Low LD[a,b]	
Dependent variables					
People phone past week	Number of person types the respondent communicated with via phone in the 7 days prior to the survey	8.12	8.91	7.20	†
People phone past 4 weeks	Number of person types the respondent communicated with via phone in the 4 weeks prior to the survey	10.08	10.75	9.29	*
Info phone past week	Number of information types the respondent communicated about via phone in the 7 days prior to the survey	4.25	4.37	4.10	
Info phone past 4 weeks	Number of information types the respondent communicated about via phone in the 4 weeks prior to the survey	5.76	6.00	5.49	
People face-to-face past week	Number of person types the respondent communicated with face-to-face in the 7 days prior to the survey	12.56	13.05	11.98	†
People face-to-face past 4 weeks	Number of person types the respondent communicated with face-to face in the 4 weeks prior to the survey	14.59	15.12	13.98	*
Info face-to-face past week	Number of information types the respondent communicated about face-to-face in the 7 days prior to the survey	5.26	5.23	5.31	
Info face-to-face past 4 weeks	Number of information types the respondent communicated about face-to-face in the 4 weeks prior to the survey	7.19	7.28	7.10	
Independent variables					
Herfindahl index[b]	Measure of income concentration (i.e., inverse of diversification)	0.69	0.54	0.87	**
Age of HHH is 24–38 (0/1)	Age of household head (HHH); *Korianga* age-set	0.35	0.37	0.33	
Age of HHH is 39–53 (0/1)	Age of HHH; *Landis* age-set	0.39	0.32	0.47	
Age of HHH is 54 or higher (0/1)	Age of HHH; *Makaa* age-set or higher	0.26	0.32	0.20	†
Education of HHH (0/1)	Measure of whether or not HHH had any formal education (i.e., attended school)	0.46	0.40	0.53	
HH Size	Total number of individuals in household (HH)	10.46	10.70	10.18	
TLU[d]	Tropical livestock units (measure of livestock holdings that accounts for differences across species)	57.40	59.71	54.72	
Land allocation	Total acres of land allocated by government to HH for private use, typically agriculture	22.80	24.22	21.15	
Total income	Total HH income from the sale of livestock, estimated value of milk off-take (incl. milk used and sold), estimated value of total agricultural harvest, remittance income, off-farm income, and income from leased lands in the 12 months preceding the survey interview. (Means reported in US dollars)	3264.51	2798.24	3806.90	
Signal (0/1)	Respondents ranked phone signal quality as good or very good in the sub-village	0.73	0.74	0.71	
Proximity to TNP	Distance from HH's sub-village centroid to TNP border (km)	41.31	42.44	40.00	

[a] Low livelihood diversification (LD) is a Herfindahl index score greater than or equal to 0.70. High LD is less than 0.70.

[b] The Herfindahl index is calculated as the sum of the squared percentage of income per source of total household income. Sources of income include: livestock, agriculture, wage labor, business activities, and proceeds from leased land.

[c] Cluster-adjusted difference in means between low and high LD tested using Student's *t* tests (continuous) or Chi squared tests (categorical). † p < 0.10; * p < 0.05; ** p < 0.01; *** p < 0.00.

[d] Tropical livestock units (TLUs) are defined here as: 1 adult zebu cow = 0.71; adult sheep/goat = 0.17 (Homewood et al., 2009).

themselves, their households do benefit from phone use. To account for this issue, our analyses focused on household heads who personally use phones. Fourth, constrained by limited resources, this study focused on households' livelihoods from the perspectives of household heads (who are generally male). While this approach has been common in livelihoods research, women's activities are part of the stories of diversification, decision making, and changes in information flows in these communities. That these are not examined here is a weakness of our study. Subsequent studies by our team will address this significant shortcoming.

4. Findings

4.1. Descriptions of phone use and livelihoods

A comment made during one group interview exemplified the tenor of the discussion in each of our interviews: "the phone is one of the best tools we have ever seen." Many described how they have "been growing up without phones" and compared the current situation to earlier times. In the past, "I wake up in the morning and have ten things… and I need to start walking." Now with a phone, "you can finish all your problems in a short time." Overwhelmingly, groups indicated how much easier it is with phones to do the things they need to do.

In the sections that follow, we divide the ways that Maasai have incorporated phones into their diversified livelihoods (RQ1) into two broad categories: uses that directly affect livelihood activities, and uses that indirectly affect livelihood activities. We also present some basic descriptive statistics comparing key types of phone-based and face-to-face communication.

4.1.1. Uses that directly affect livelihood activities
4.1.1.1. Livestock production and trade.
Even as Maasai diversify their livelihoods, livestock production remains the centerpiece of their activities. Basic feature, mobile phones support these activities in several ways that range from herd development to market-based transactions. Herders use phones to locate forage and water, which can be challenging in a patchy, dynamic landscape. Herders can call friends and relatives to ask if it's rained recently in a particular area and whether new grass is available. This information can help to make herd movements more efficient in terms of distance traveled for calories consumed. Phones also allow herders to communicate easily about their own needs or the needs of the animals they are herding. If either an animal or a herder becomes sick, medicine or other resources can easily be requested. Herders can also use phones to manage human-wildlife conflict by communicating with each other about the whereabouts of dangerous animals or to request emergency assistance if the herd is attacked. This can reduce the incidence and severity of wildlife attacks.

Phones have also become instrumental in market-based activities. Most livestock transactions take place at cattle markets, which can be far from local communities. Before phones, livestock owners would send the animals they wished to sell to market with handlers who were instructed to negotiate for the best price. Handlers would then walk the animal to the market and the owner played no further role in the transaction. With phones, sale prices can be communicated with ease and buyers and sellers can participate remotely – giving owners greater control over the transaction. Similarly, buyers and sellers can use phones to identify price differences between markets to select the venue that best serves their interests. With phones, it is no longer necessary to walk an animal to market to prospect for good prices. Pictures of animals taken with phone cameras can be shown widely to potential buyers. Along these lines, phone calculators have also become useful tools.

4.1.1.2. Agriculture and weather forecasting.
As with livestock production, phones are becoming integral to most farming activities. For decades, Maasai in this area have incorporated rain-fed agriculture

into their livelihood strategies. However, persistent struggles with limited technical know-how, crop predation by wildlife, and highly variable rainfall have undermined agricultural efforts. With phones, Maasai are better able develop connections with outside groups of experienced agricultural laborers, tractor owners, seed retailers and agricultural extension agents. A key to success with agriculture is timing the preparation and planting of fields just as the rainy season is beginning. In the past, acquiring information about seeds, scheduling tractors and coordinating laborers efforts all took time. Phones now greatly facilitate these activities. They also help Maasai to forestall predation by coordinating guards' efforts, exchanging information about wildlife activities, and organizing groups to haze certain agricultural pests (e.g., baboons) out of an area.

One growing use of phones to support agriculture involves tapping online weather forecasts to identify when to plant seeds. For most individual Maasai, this is a highly sophisticated application of the phone that surpasses their technical abilities. We were repeatedly told that low levels of literacy, especially among older Maasai, precluded the use of most applications beyond calling. But for a few who are highly experienced users, phones can be used to predict the weather. One such individual was described during a group interview as the "phone *laibon*." *Laiboni* (plural of *laibon*) are the traditional spiritual authority figures in Maasai society, or medicine men. While their influence is fading with the advance of Christianity in Maasailand, people have visited them to help with various problems and to see into the future. We had an opportunity to meet with this "phone *laibon*." He told us that he gets calls from four regions (i.e., states) within Tanzania and from Kenya. Specifically, people call him to ask when it will rain in their area. He uses a smart phone and described how he "understand[s] maps, GPS, and weather." He gets calls every day but the volume really picks up between November and May. Unlike actual *Laiboni*, he does not accept gifts or payment for his service. He also noted that he is not teaching people how to use phones − only providing information.

4.1.1.3. Other income activities & new livelihood challenges.
Mobile phones are also widely used for other income generating activities and for transferring money between parties. Wage labor migration to urban areas, like Arusha, has become common, especially for young men seeking to support their rural households through remittances. Phones help migrants to stay connected with sending areas and leverage social networks in fast-paced urban areas. And new mobile banking applications, like M-pesa and Airtel Money, allow users to send and receive funds through accounts linked to their phones. In Mererani, where Maasai have established themselves as gemstone brokers in the profitable Tanzanite mining industry, phones have also been instrumental.

When asked whether phones were adding new challenges or problems to their lives, a common response was reflected one respondent's comment that the "phone doesn't have problems… people have problems." As examples of this, several groups described how phones have been used by "bandits" or "robbers" to facilitate theft and violence. Scenarios were described wherein individuals or groups carrying large sums of money, perhaps returning from a market, would be ambushed along the road. The implication here is that market snoops use phones to pass information about who is carrying money to roadside attackers. A related concern was more direct. One respondent noted that "your enemies call… use it [phone] in a bad way." In these cases a person may receive a call, perhaps from a stranger pretending to know him, requesting him to come to a certain area for a meeting or something else – and be ambushed en route. This is especially the case for Maasai working as brokers in and around Mererani. This was described as an early problem with phones. Increasingly, however, people are learning how to look up numbers and this particular problem is waning.

4.1.2. Uses that indirectly affect livelihoods
4.1.2.1. Households, health and community.
Historically, Maasai

economic activities and social dynamics have been closely linked. From this perspective, several other factors, including household organization, health care, and community governance affect Maasai livelihoods. As may be expected, mobile phones have been used to support these activities as well. Women use phones to communicate with other wives within or between bomas about daily activities like monitoring children, gathering fuelwood and other materials, or preparing food. Phones have also proved invaluable for all manner of health crises. Complications with pregnancy, especially stalled labors, were highlighted as examples of how phones can be used to call for assistance and save lives. And community leaders and administrators now rely on phones to help organize all manner of group meetings. Before phones, all of these types of communication occurred face-to-face, either through a messenger on foot or directly between parties.

Phone-based applications, which are available on basic phones, have also become important new tools for facilitating access to information and resources. These include simple applications like clocks, calculators and lights, which are common on most phones, but others exist. Phone-based radios allow users to listen to the news, including government messages. Memory cards can be used to store things like songs ("church music" was offered as an example). And increasingly users are setting up email accounts, which they can access from even basic phones. Younger people are even accessing apps like Facebook and WhatsApp to share photos, send messages and flirt. (Table 3 presents percentages of respondents using various phone applications.) When asked if there were any things the phone was not used for, a single example was provided: marriages must be arranged between families face-to-face. This was described as an issue of respect.

4.1.2.2. Community challenges: dishonesty and individualism. Group interview participants also indicated that phones were creating new challenges for people. Specifically, they provided examples of how phones are have been associated with an erosion of community including forms of dishonesty, growing infidelity, and reduced civic engagement.

One respondent pointed out "phones also lie." A common challenge identified by multiple groups was that phones were exposing, or fomenting dishonesty, and undermining trust between individuals within local communities. A common way this happens is that an individual reaches out to a contact to meet and the contact lies and says that he cannot because he is outside the village, perhaps in the city. Later that day, however, the two encounter each other in the village and the lie is exposed. When asked why a person would lie to avoid someone, we were told that the caller may be looking for a favor and the contact would prefer not to help. Respondents also described how people may lie about issues such as the availability of forage or water so that distant herders do not travel to a particular area.

Phones have also compounded existing challenges for Maasai. In polygynous societies, where men take multiple wives, the ratio between unmarried men and unmarried women can be quite skewed. Among Maasai it is common for marriages to be arranged between young

Table 3
Percentages of respondents using phone applications in past 4 weeks or ever.

Phone applications	Past 4 weeks	Ever
Calculator	0.80	0.83
Radio	0.75	0.83
Camera	0.62	0.76
Banking (receiving)	0.58	0.74
Banking (sending)	0.58	0.73
Facebook	0.15	0.23
Email	0.10	0.17
What's App	0.08	0.21
Other internet	0.05	0.12
Weather information	0.04	0.15

women and much older men who already have multiple wives. Respondents described how young women are often not happy with this arrangement and may have young boyfriends they wish to be with. "Cheating" was described as big and longstanding problem across Maasailand. Now, phones greatly facilitate this cheating. Young wives can easily flirt and arrange rendezvous with their boyfriends behind their husbands' backs. As may be expected, these activities have added strain to the relationships between generations of men.

Several group-interview respondents indicated how it is much more difficult to organize meetings now compared to the past, despite the greater ease of communication and transportation. In the past, foot messengers would be sent to notify people throughout the village about upcoming meetings − and attendance was strong. Now, phones can be used to send notices quickly, but meeting attendance has dramatically declined. Furthermore, it is more difficult for groups to reach a consensus as dissenting opinions are more widely expressed.

Lastly, the growing use of mobile phones has activated, for some, deeply rooted beliefs and anxieties about supernatural forces. In one group interview, respondents described stories Maasai had heard of people receiving calls from truncated numbers (e.g., 999) who instantly died upon answering the calls. News stories of incidents from Dar es Salaam and Dodoma were recounted and group interview participants were dismayed by this apparent manifestation of witchcraft. Notably during this interview, respondents also expressed concern to researchers about phantom vibrations they sometimes feel where they normally carry their phones. Despite the broad value of phones for supporting livelihoods, Maasai perceptions of this new tool are tinged with these types of mystery and unease.

4.2. Quantitative findings: phones and ID

The results of the regression analyses of the association between LD and measures communication (RQ2) are presented in Table 4 and Fig. 2. Our discussion below focuses on the effects of LD, but it is worth noting that the effects of control factors are largely consistent across comparable outcomes and not significant. One exception to this is our measure of phone signal, which was positively and significantly associated with each measure of phone-based communication and one measure of face-to-face communication.

As expected, LD (as measured by the Herfindahl index) was significantly associated with communication outcomes when controlling for other factors (see Table 4). With model specification 1, the effect of LD was significant (i.e., $p < 0.05$) for each outcome except face-to-face communication about types of information. With model specification 2, the effect of LD was significant and non-linear for seven of the eight dependent variables. Taken together, the findings presented in Table 4 reveal that the effect of LD on information is largely positive (i.e., the effects of concentration are negative) but that the relationship is curvilinear with steepest increase in communication types at higher levels of LD (i.e., at low Herfindahl index values). To further illustrate these relationships, Fig. 2 presents predicted values of communication by type using the non-linear specification of the Herfindahl index, which provided the best overall fit. This confirms that ID is highest at the lowest level of the Herfindahl index (i.e., highest LD).

5. Discussion

The qualitative results of the study provide evidence that mobile phones: (1) support a broad range of Maasai livelihood activities by facilitating communication between individuals and groups; and (2) have introduced some new communication-related challenges (RQ1). These findings also illustrate the ways in which Maasai have adopted mobile phones as critical new tools to manage relationships, resources and risk − a topic on which there is relatively little research (Butt, 2014; Lewis et al., 2016; Msuya and Annake, 2013).

Phones have become key tools to support diversified livelihoods.

Table 4

Poisson regression models of phone-based and face-to-face communication, including types of communication partners (i.e., people) and types of information exchanged (i.e., info).

	Phone-based communication				Face-to-face communication			
	People	People	Info	Info	People	People	Info	Info
	1 week	4 weeks	1 week	4 weeks	1 week	4 weeks	1 week	4 weeks
Model specification 1								
Livelihood diversification								
Herfindahl index	− 0.43**	− 0.33**	− 0.34***	− 0.37*	− 0.28*	− 0.25**	0.05	− 0.07
HH demographic measures								
HHH is age 24–38 (0/1)	− 0.15	− 0.10	− 0.06	− 0.10	− 0.04	− 0.06	0.07	0.00
HHH is age 39–53 (0/1)	0.11	0.12	0.20	0.15	− 0.04†	0.00	− 0.11	− 0.05
HHH education (0/1)	0.02	− 0.03	0.06	0.01	0.07	0.06†	0.13	0.10
HH size	0.00	0.01	0.01	0.00	0.00	− 0.00	0.01	0.00
HH economic measures								
TLU (ln)	− 0.04	− 0.03	− 0.01	0.00	0.00	0.00	0.07	0.02
Land allocation (acres)	− 0.00	− 0.00	0.00	0.00	− 0.00	− 0.00***	− 0.00	− 0.00
Total income (ln)	0.10	0.09	− 0.05	− 0.01	0.05*	0.07**	− 0.09	0.01
HH spatial measures								
Good phone signal (0/1)	0.32***	0.26**	0.89***	0.73***	0.01	0.05	0.40†	0.27*
Proximity to TNP	0.00	− 0.00	− 0.01	− 0.01	0.00	0.00*	0.00	− 0.00
N(households)	106	106	106	106	106	106	106	106
Model specification 2								
Herfindahl index	− 0.16	− 1.18	− 3.18*	− 2.64	− 0.77	− 0.84	− 4.43***	− 3.64***
Herfindahl index (sq)	− 0.20	0.61	2.03†	1.63	0.36	0.42	3.19***	2.56***
Significance	*	***	**	*	†	*	***	***

Reference categories are age 54 or older, no education, and phone signal average or below. † p < 0.10; * p < 0.05; ** p < 0.01; *** p < 0.00.

They help herders to locate spatially variable resources, manage interactions with wildlife, and interact with markets – findings that align with other studies of Maasai herders (Butt, 2014). For these reasons alone, one respondent noted "the phone has come at the right time." During another interview a respondent commented, "as Maasai, we don't have many skills with cultivation." With phones, households are better able to coordinate with outsiders for labor, materials, and information – including crucial weather forecasts. As other studies have found, phones also promote efficient engagement with markets (Aker, 2010; Muto and Yamano, 2009; Debsu et al., 2016). And phones have
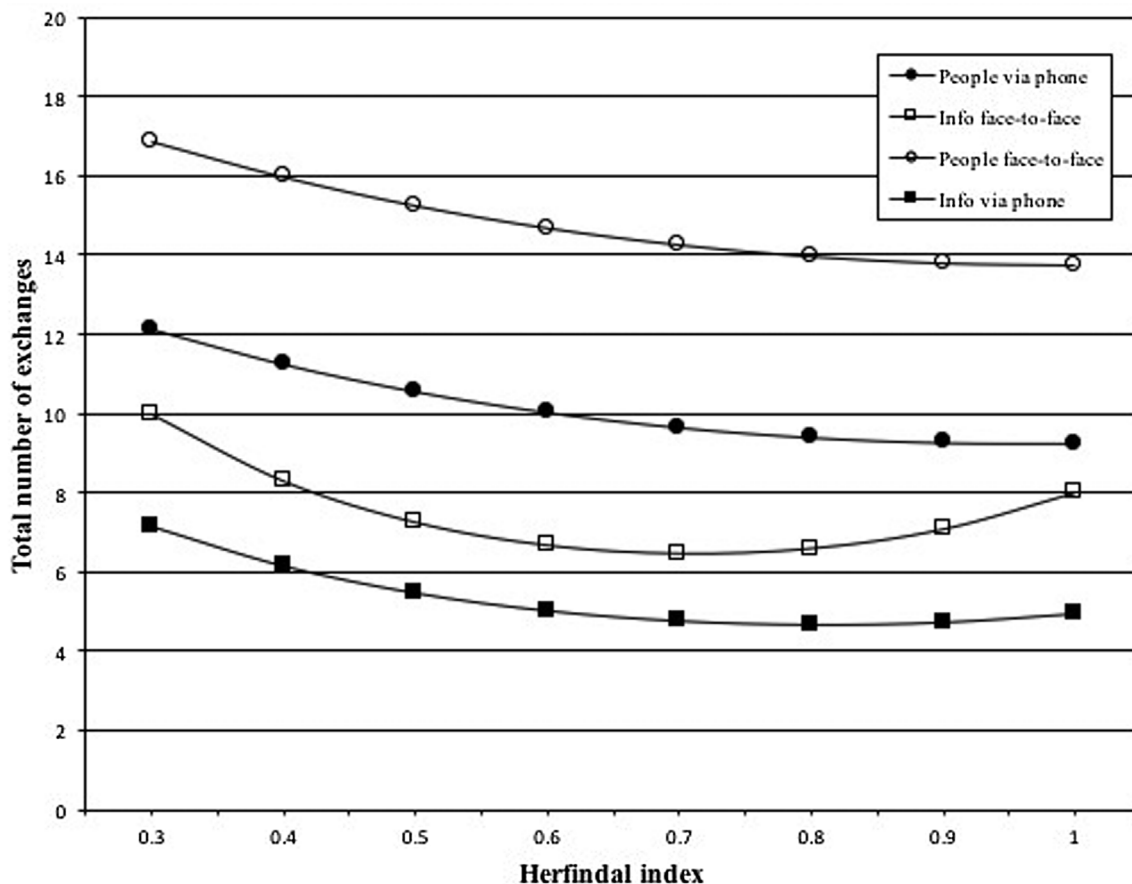

Fig. 2. Predicted values of communication, in past 4 weeks, by type and measure of livelihood diversification (i.e., Herdindahl index) with mean values of the other predictors.

been a life-saving technology in the case of medical emergencies. Respondents also highlighted many other useful phone-based tools and applications, especially mobile-money services, which more than half of survey respondents had used in the four weeks prior to the survey (see Table 3). Women use phones for to facilitate all types of domestic activities and young children can be seen holding rocks or sticks up to their ears, pretending to talk on the "phone."

Mobile phones have also introduced new challenges. Herders can spread misinformation regarding water and forage, heightening the relevance of social networks, as other studies have found (Butt, 2014; Debsu et al., 2016). Our qualitative findings are also well aligned with studies of other populations in Africa, which have found that phones have: undermined trust and created to new relationship challenges (Archambault, 2011); been perceived as instruments of witchcraft (Mcintosh, 2010); supported new forms of criminality (Hahn, 2012); and upended inter-generational power dynamics (Porter et al., 2015).

The qualitative findings, however, do not suggest that mobile phones have necessarily transformed Maasai livelihoods. Group interview respondents described many instances of how phones are being used to support existing activities, like herding and agriculture, but few examples of entirely new endeavors or even new types of communication partners. This finding specifically is well aligned with other studies of pastoralists and other developing groups, which have found that new technologies can become embedded in existing systems rather than transform them (Butt, 2014; Donner and Escobari, 2010).

Despite our small sample size, the quantitative results of this study provide strong evidence that LD is positively associated with ID for household heads who use mobile phones (RQ2). This relationship applies to phone-based and face-to-face forms of communication for various types of communication partners and about various types of information. Furthermore, the effect of LD on ID is greatest at the highest levels of diversification. This finding provides early support for a working hypothesis that LD draws people into new social and economic networks and provides wider access to diverse information. Phones may simply catalyze this ongoing process.

Taken together our qualitative and quantitative findings may also signal a coming shift within Maasai social networks. Currently, Maasai are largely using phones to expand communication with familiar individuals and groups. Within these bonded, comparatively homogenous, networks members each have similar experiences, perspectives, tools and information. These types of networks, which help individuals and groups get through difficult situations (Gittell and Vidal, 1998; Putnam, 2000), characterize pastoralist groups (Baird and Gray, 2014). But as Maasai become more familiar with mobile technologies, new uses and communication partners may take root and reshape social networks and norms. More heterogeneous, bridged networks may form where members come from diverse backgrounds and have access to different skills and information. These types of networks can help their members to prospect for new opportunities and advance (De Souza Briggs, 1998). It follows, that as Maasai diversify, and experiment with new technologies, they may shift between these types of social networks.

Looking forward, two items to consider are: (1) barriers to, and (2) challenges with, this potential shift. Our findings reveal potential barriers to a shift in social network types. First, the high level of illiteracy among Maasai limits the use of many phone-based tools. One respondent commented, "most of us call… not like you [researchers] who are always using your fingers." Second, many Maasai remain suspicious of phone-based communication, which has been viewed as a new tool of dishonesty, infidelity, banditry, and sorcery – concerns that have been identified in other developing contexts (Watson and Duffield, 2015; Watson and Atuick, 2015). Third, Fig. 2 shows that face-to-face communication is more common than phone-based communication for partner- and information-types. Given the comparative ease of phone-based communication, this suggests that many Maasai have not yet built their networks far beyond the scope of their immediate physical

surroundings. Relatedly, Donner and Escobari (2010, 641) have argued that phones are more likely to "amplify existing material and information flows rather than transform them" .

Despite these barriers, new challenges associated with LD and mobile phones suggest that some social changes are already occurring. Namely, traditional power and information hierarchies may be changing. First, Maasai patterns of social organization are closely tied to traditional pastoralist modes of production. As households diversify into other activities, social norms related to communication or reciprocity may or may not apply (Baird and Gray, 2014). Second, as tools, phones privilege the educated, who are more likely to be young than old. This contrasts with customary Maasai social order, where power, knowledge and influence are consolidated among older generations. Now, instead of asking an elder, people may reach out to an expert. Instead of working with a friend, people may hire an outsider. Instead of trusting a neighbor, people may make their own decisions. Even young girls are using phones to gain an edge in their struggle against the strictures of traditional polygyny. Beyond infidelity, girls are pressing to attend school, delay marriage, and choose their own husbands.

6. Conclusion

The goal of this paper was to describe the relationship between Maasai LD and ID within a context of rapid mobile-phone adoption. The relevance of these issues was driven home for us during one group interview when a respondent stated, "a good herder always brings information, even without a phone." While it may be tempting to describe how powerful new technologies are transforming rural livelihoods and land uses, our findings suggest that, thus far, Maasai have used phones to support their existing activities rather than transform them. This should not necessarily come as a surprise, however, given that innovations are frequently adopted precisely *because* they are compatible with existing activities and values (Rogers, 2010 [1962]). However, innovation and social change are each processes that require time. For Maasai communities, the incorporation of mobile technologies within their lives and livelihoods may represent an early phase of a protracted transformation that could ultimately reshape social networks, land use, and ecosystems.

LD itself has been viewed as a type of transformation. Scholars of Maasai LD have argued that the shift towards diversification is linear and permanent (McCabe, 2003; Homewood et al., 2009). Once pastoralists branch out to incorporate new economic activities, like agriculture, they are unlikely to go back to strict pastoralism. Here, we find that diversified livelihoods (LD) yield more diverse information flows (ID). This raises the question of whether increases in ID will also continue – and what the implications of this may be for land use and human wellbeing.

From a land use policy perspective, trends towards individualism may currently have a greater effect on land use challenges than mobile phones. Diversification has led to the privatization of land and encroachment of agriculture on communal grazing areas and lands important for biodiversity. Furthermore, declines in reciprocal exchange, linked to LD, were evident even before phones were widespread (Baird and Gray, 2014). Policy makers and researchers must strive, therefore, to understand the contexts in which technologies are used. During the early phases of adoption for example, land use may drive technology (as we see here) more than technology drives land use. In this way, land use can be seen as a cause rather than an effect.

In the future, however, the effect of mobile technologies on land use is likely to grow. Greater access to information may increase returns to various land uses (e.g., herding, agriculture, etc.) and could potentially decrease (or increase) land conversion and degradation. Also, phones may serve to catalyze social tensions that undermine group efforts to manage common property effectively. As mobile communications become more common, even essential, policy makers should consider

strategies to: preserve social institutions that manage shared resources; reduce infrastructural inequalities that limit access; and promote the availability of high quality information. Furthermore, policy makers should reflect on the growing incentives that LD and phones provide for formal education and skills training in rural areas where land use is expanding.

Acknowledgements

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