



When is migration a maladaptive response to climate change?

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Abstract

Climate change affects rainfall variability and food security, in some cases leading to migration. Improved understanding about the interactions between climate and food security is needed before we can determine whether migration is a truly adaptive response in poorer countries. Without this understanding, it is difficult to design effective strategies that ensure climate resilient development. We present an analysis of climate, food security, migration, and its consequences from 218 households in three locations in North-western Cambodia, the most climate vulnerable nation in SE Asia. Results show that migration occurs in up to 45% of households, over half of which is climate-related. Migration causes labour shortages and welfare issues, but does not necessarily improve food security. This and climate trends lead us to argue that migration may be maladaptive over the long term, resulting in a climate-induced poverty trap. Instead, livelihood adaptations are needed that address (i) changing community demographics resulting from young male migrants, (ii) migration seasonality, associated labour shortages and gender role implications, and (iii) the burden of food insecurity. Only then can we avoid the maladaptive climate migration poverty trap.

Keywords Food security · Adaptation · Cambodia · Resilience · Gender

Introduction

Climate-related impacts can be sudden or gradual, and interact with political, social, economic, and demographic drivers influencing household member(s) choice to migrate (Black et al. 2011a). Clear evidence of migration as an adaptation strategy to increased rainfall variability and food insecurity has been reported from Ghana (Abu et al. 2014), Tanzania (Afifi et al. 2014), Guatemala (Milan and Ruano 2014),

Bangladesh (Etzold et al. 2014), Mexico (Feng et al. 2010), and Vanuatu (Craven 2015). Alternatively, countries may have a culture of migration independent of or complicated by climate projections, e.g. Tuvalu and Kiribati (Barnett and O'Neill 2012; Connell 2014).

Migration studies typically emphasise ‘push’ factors (within context of origin) or ‘pull’ factors (context of destination) (Muriuki et al. 2011), and may be environmental, social, political, economic, or household-related (Black et al. 2011c). Understanding the relationship between climate change and migration focusses on push factors. Adaptation that addresses climate change may or may not affect migration, depending on the relative strength of pull factors. A predominant thesis on migration is that a ‘survival threshold’ exists, above which migration provides a means of diversifying economic risk through migration of surplus labour or skills (Sakdapolrak et al. 2014; Ng'ang'a et al. 2016). In these cases, the cost of migrating results in educated and older migrants (Suckall et al. 2016). Below the ‘survival threshold’, migration drivers include debt and food insecurity; the latter is sometimes addressed through migrant remittances (Craven 2015; Kuire et al. 2013). Climate-related migration can also lead to a loss of skills, knowledge, and labour from a community (Craven 2015; Etzold et al. 2014; Warner and Afifi 2014). Thus, the demographics and reasoning for migration (including climate

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change), and subsequent impacts and response options are highly varied. Migration has the potential to be either an adaptive or a maladaptive response to climate change over the long term.

In Southeast Asia, the relationship between climate, food security, and migration has received little attention (Black et al. 2011b). Unlike in other regions, families in Eastern and Southeastern Asia are retaining rural landholdings despite their diminished economic importance (Rigg et al. 2016). Poverty has reduced, albeit more slowly in rural areas than in urban areas (Ibid). Vulnerability to climate change is also widespread, and highest in Cambodia (Yusuf and Francisco 2009). Evidence suggests climate and food insecurity are already affecting migration. The Cambodia Rural Urban Migration Project (Kingdom of Cambodia 2012) estimates out-migration at 22%; soil erosion, poor harvests, and disaster were all problems in at least half of rural cases. Analysis of the 2015/6 El Nino drought impacts (FAO, WFP, and UNICEF 2016) indicates that 29% of households in the Tonle Sap region (Northwestern Cambodia) experienced rice paddy loss and 19% experienced income loss. Annual average migrant remittances of 1130USD (Kingdom of Cambodia 2012) may have alleviated some of the unexplained food security impacts in the region. Understanding these interactions and the consequences of climate-related migration is essential in the design of effective adaptation strategies (Carr and Thompson 2014). Migration in Northwestern Cambodia is comparatively understudied compared to the Mekong River (e.g. Van Wensveen et al. 2016; Bylander 2015), despite the role of the Northwest in food production (Kingdom of Cambodia 2013), and despite agriculture being proposed as a solution to ongoing fisheries decline in the Tonle Sap fishery (Sassoon 2017). This article aims to understand the relationships between climate change, migration, and food security in Northwestern Cambodia, emphasising push factors and the consequences of migration on those who remain. It addresses gaps in regional understanding about these relationships, questioning the long-term adaptive nature of climate- and food insecurity-related migration. We follow a typical article structure, detailing methods (including study sites), results, discussion, and conclusions; our discussion focusses on the climate-poverty nexus and whether migration is an appropriate response to this.

Methods

Case study selection

We sought to understand whether migration was adaptive or maladaptive by addressing the following questions:

- How is the climate changing?

- What rates of migration exist and what are the drivers of it?
- What are the consequences of migration for remaining communities?

This study focusses on three communities in different locations surrounding the Tonle Sap Lake (Fig. 1). Lvea Krang (Varin District) is a remote subsistence community in the foothills of Kulen Mountain, equidistance between the Siem Reap and the border at Anlong Veng. There is no power or running water, and key crops include rice and cassava. Popok (Stoung District) is a remote community but one with power and water and diversified livelihoods including rice, cassava, and cashew nuts. Chamkar Samrong is a peri-urban community on the outskirts of Battambang City, with only 30% land in agriculture production (rice and some fruit trees); many residents work in the city, or own agricultural lands in the surrounding district. These communities were part of a research partnership between the UN Food and Agriculture Organisation (FAO) Life and Nature project (focussing of watershed management and climate adaptation) and an Asia Pacific Network for Global and Regional Change project on community resilience. Two other FAO case study communities (in Preah Vihear and Ratanakkiri provinces) were sampled but are excluded given low rates of migration (< 15% households surveyed)—most likely due to localised border sensitivities—and thus very low analytic power.

While the focus of our study is the inter-relationship between climate, migration, and food security, we recognise relationships between migration and social status (e.g. land parcel size, productivity, access to resources). Bylander and Hamilton (2015) analysed 2009 Cambodian Socio-Economic Survey data to explore socio-economic homogeneity and migration. They argue that migration has historically been seasonal. Migrants (9% of households) were generally of moderate wealth, less educated, own land, and are less food-insecure, but have greater access to formal credit. They argue that migration and taking loans are a combined coping strategy, given that migrants struggle to put credit to use in secure ways. Their data is however quite old and may not still be accurate in a rapidly evolving economy such as Cambodia. Specific socio-economic detail about our study sites was not available a priori.

Climate change

We analysed climate change trends by comparing patterns in MODIS-derived normalised difference vegetation index (NDVI), at the district scale. Satellite-derived normalised difference vegetation index (NDVI) offers new opportunities to assess climate fluctuations (Buitenwerf et al. 2015). The premise is that NDVI is an indicator of vegetation health, and a decrease in greenness would be reflected in a decrease in NDVI value. Change in precipitation is also highly correlated

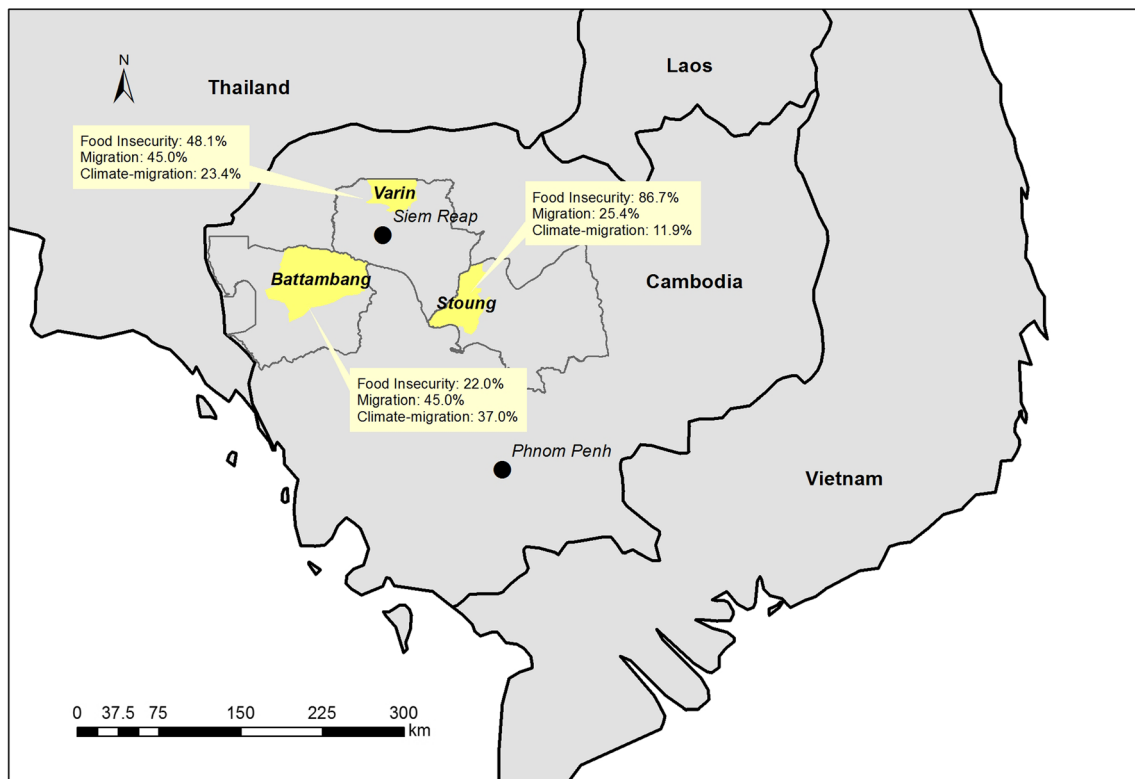


Fig. 1 Case study locations

with changes in NDVI (Verbesselt et al. 2016). In this article, in absence of reliable precipitation data, we used remotely sensed NDVI time series as an indicator of fluctuations in precipitation. NDVI has been used extensively (including in Cambodia) to assess crop cover (see Gauhan et al. 2009). Son et al. (2012) demonstrate the use of NDVI in assessing drought severity between 2001 and 2010; extreme droughts occurred in 2003 and 2005, and that the mildest drought occurred in 2009/10. Records also demonstrate that NDVI has advantages over other in situ data, in that it is economically collected and analysed. Changes in crop production (reflected in NDVI) at important times of the year could result in changes in food security, including August–September (wet season) and May (early-wet season, where planting rice is risky). This data also enables us to appraise whether our migration and food security data represents a typical or atypical year.

Migration, its drivers, and consequences

Survey data was collected from 10% of households in each community, sampled using a systematic random design using every 10th household from each village; in Chamkar Samrong, only villages 1 and 2 were selected, given that most remaining agricultural land exists in these villages. Each community was sampled over a period of a week between February and March 2016. Respondents worked with enumerators (in Khmer language) to complete the survey; we had

zero non-response rate, and provided limited incentives (1USD equivalent in goods for participation lasting on average 20 min). We sampled a total of 219 households, 60 from Lvea Krang, 59 from Popok and 100 from Chamkar Samrong.

Questions related to migration (for up to two migrants per household, defined as working outside of the district) included:

- Demographics of migrants and families with migrant member(s) (age, gender, work type, family size, number of months away from community per year, average remittances);
- Causes of migration (multiple responses allowed, including food insecurity, economic, climate-related, and other responses); and
- Consequences of migration, including positive responses (less violence, improved living standard, education, or food security) and negative responses (decreased food security, labour shortage or cost, child welfare, women's welfare).

We report descriptive statistics, comparing households with and without migrants. For migration causes, we created four specific response groupings: (1) food insecurity; (2) 'climate related', including bad harvest, agriculture, and natural disaster; (3) 'economic', including debt and income; and (4) other. The inclusion of 'bad harvest' as a climate-related variable

was based on discussions during vulnerability impact assessments that acknowledged community perceptions that this was driven by (flash) flooding and drought that caused rotten crops or lack of seedling maturity. We then excluded responses that identified a ‘climate-related’ cause from economic causes into ‘economic-adjusted’, given that such funds are typically used to pay for debt associated with seed, labour, and food associated when harvests are poor or affected by disaster (WFP, UNICEF, and FAO 2016). The resultant category ‘economic-adjusted’ therefore reflects pre-existing debt, education, and other costs such as those arising from marriage.

We used a binomial Coping Strategies Index (Care 2003) to investigate food insecurity and the use of food insecurity coping strategies in each of the 12 months prior to the survey. The Household Food Insecurity Access Scale (HFIAS) and variants are currently used by the FAO to assess food insecurity (Cafiero et al. 2014). However, the Coping Strategies Index can be aligned with seasonal issues where migration is temporary, and is more robust for a development context where food variety and resources to access preferred foods limit the sensitivity of HFIAS (Carletto et al. 2013; Heady and Ecker 2013). It also enabled us to consider how migration interacts with other strategies that could address food insecurity, and therefore to assess its effectiveness as an adaptation strategy. Coping strategies included harvesting immature crops, using famine foods, purchasing food, limiting women’s access to food, borrowing money to buy food, selling assets to buy food, or migration. For analysis, we compared the prevalence of coping strategies. This provides an understanding of strategy sequencing, including the sequencing of migration in comparison to other strategies, and thus the likely success of adaptation initiatives. In all cases, data interpretation is supported by vulnerability impact assessments (VIA) that included historical timelines of climate events and their impacts, and seasonal calendars related to climate events and agricultural practices.

While we did not interview migrants themselves, ‘pull’ factors may also influence migration. The majority of migrants to the Cambodian capital city work in garment factories, as construction labourers or in small business, gain a job within a month, have more assets than rural counterparts, and earn 62–240USD per month (KoC 2012), whereas agricultural workers earn a maximum of 100USD/month (World Bank 2015). Rural poverty rates are nearly three times those in urban areas (Rigg et al. 2016). Destination labour conditions are therefore a potential pull factor, and work is clearly not seasonal in nature. Over half of migrants to the capital city were helped by a friend or relative, and more than 14% have help a friend or relative migrate, while > 80% return home at least once per year (KoC 2012). This indicates that person-to-person networks facilitate internal mobility, with institutional structures such as unionised labour resulting in increased wages.

OECD analyses of international migration (2017) indicate non-seasonal employment in construction (25%), fisheries (12%), and agriculture (19%)—predominantly in Thailand where crop diversification provides labouring opportunities year-round. Anecdotal discussions within communities indicate that informal international migration is facilitated through family networks or through an agent, at a fee (requiring access to microfinance or cash reserves). Institutional structures also shape mobility. Formal migration to Thailand requires visa and permitting, which may or may not be enforced; recent shifts towards Thai enforcement of migrant permitting are accounted to have resulted in more returnees (<https://www.khmertimeskh.com/5065218/thai-migrant-exodus-reaches-90000/>). However, community discussion on reasons for seemingly empty houses in Lvea Krang (unpublished data, 2017) indicate that whole families are migrating to Thailand irrespective of this. OECD analyses also indicate that receipt of agricultural subsidies are linked to migration, but this ought to be read with caution; the need for a subsidy (e.g. rice production bonus price) and the need to migrate may be caused by the same driver (i.e. agricultural productivity).

Results

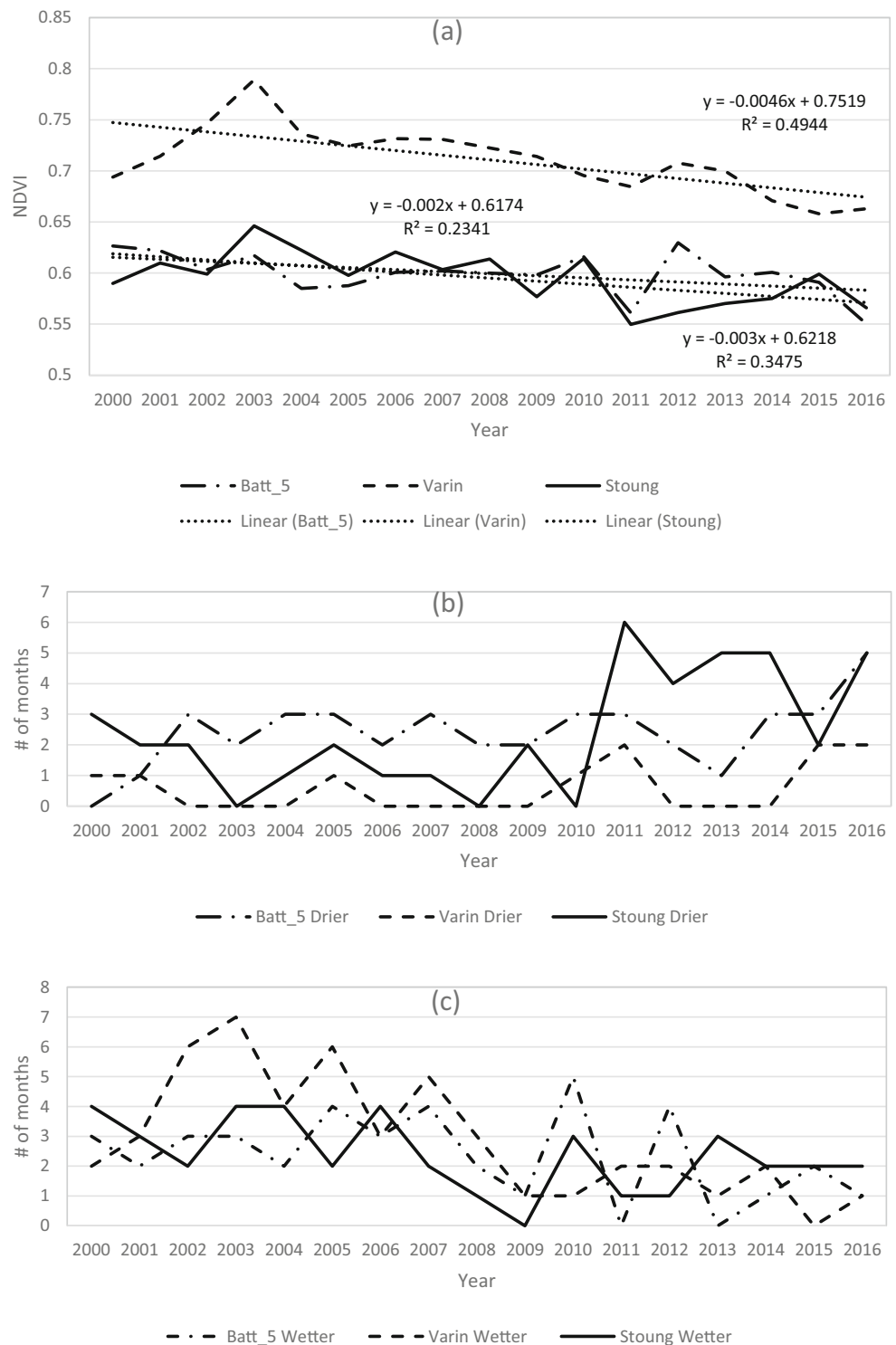
Climate change

NDVI (2000–2016) analysis shows a trend towards drying (Fig. 2a). While we acknowledge that 2015/2016 was one of the most significant droughts on record (WFP, UNICEF, and FAO 2016), this trend is still true if 2015/2016 data are excluded (2000–2016: $R^2 = 0.49$ vs. 2000–2015: $R^2 = 0.42$). Trends also show increased variation in the number of abnormally wet months per year, and in the number of abnormally dry months per year (Fig. 2b). Results indicate that 2015/2016 was abnormally drier in both Battambang and Stoung districts, but not in Varin. This is also evident from the ratio of drier to wetter years of three sites (Battambang 5/1, Varin 2/1, and Stoung 5/2). This ratio was above the long-term average of 1.4, 0.4, and 1.4 for Battambang, Varin, and Stoung, respectively. According to FAO, WFP, and UNICEF (2016), 2015/2016 was the most significant drought in the past 50 years in Cambodia, and these results concur with this.

Migration and its drivers

The number of households with at least one migrant (from hereon referred to as migrant households) varied from 25.4 to 46.7% across communities, and rates for two or more migrants varied from 5.4 to 23.0% (Table 1). In all communities, most primary migrants (58.3–75.0%) were men, younger (average ages between 22.5 and 25.2 years old), and displaced for between 7.8 and 9.5 months per year. Secondary migrants

Fig. 2 NDVI data. **a** Annual trend of NDVI at three sites from 2000 to 2016. **b** Number of wetter than normal. **c** Number of drier than normal months in each year for the period 2000–2016



were more commonly women (72.7%, 66.6%, and 44.0%), between 21.2 and 23.6 years old, and displaced for 6.0–10.0 months per year. Average family size varied between 3.9 and 5.7. In some cases, migrants were from statistically significantly larger households (Lvea Krang, *t* test, $p = 0.0126$, Chamkar Samrong, $p = 0.000$), although the relationship did not hold for secondary migrants. Where destination

was recorded, international migration was most common in Lvea Krang and Chamkar Samrong, and Phnom Penh was most common for migrants from Popok. Remittances from primary migrants varied, averaging \$307–\$834 per annum depending on location, with higher remittances from communities closer to the Thai border. Averaged secondary migrant remittances varied from \$604–\$687 per annum.

Table 1 Migrant statistics

Location	Primary migrant			Secondary migrant		
	HH%	Gender (%)	Age (mean; years)	HH%	Gender (%)	Age (mean; years)
Lvea Krang (<i>n</i> = 60)	45.0	81.5 M	23.4	18.3	72.7 F	21.4
Popok (<i>n</i> = 59)	25.4	53.3 M	25.2	5.1	66.6 F	23.3
Chamkar Samrong (<i>n</i> = 100)	45.0	62.2 M	22.6	25.0	56.0 M	21.6

When asked about the reasons for migration (primary migrants), economic reasons were most common, followed by climate-related reasons, and other (e.g. education, disease of healthcare). We sought a means to account for the inter-relationships between economic, climate and food insecurity reasons. That is, to separate migration for the purposes of economic advantage not related to current agricultural livelihood from other reasoning. Through field observations, we knew that climate-related issues often led to food insecurity and subsequently, to economic concerns (for information on the links between debt and agricultural activities in Cambodia see Bylander and Hamilton 2015, and FAO, WFP, UNICEF 2016). Given the interconnectedness of economic and climate-related reasons, and that climate-related issues are less apparent to community members, we conducted additional analysis removing climate-related reasons from economic reasons where both were identified. In doing so, climate-related reasoning becomes more prominent (Table 2), particularly in communities where migration is highest. If we remove both climate-related and food insecurity reasons from economic (justified given the inter-connected issues of food-security, climate, and production requirement forecasting), economic reasoning on its own is a much less significant reason for migration.

The effects of social status on mobility were explored using additional unpublished FAO data to test relationships between migration and land size, and primary crop productivity in both Lvea Krang and Popok; there were no statistically significant relationships ($p > 0.05$). In > 85% of cases in each community, members own land and, in all cases, have secure access to land. Criteria for the selection of these communities in the FAO project was not poverty-related, but may have been inadvertent due to late liberation from Khmer Rouge.

Determining social status complex, as it requires analysis of family wealth networks. Access to and use of microfinance and family borrowing may however indicate class. While not recorded in our 2016 analysis, subsequent unpublished 2017 data shows no statistically significant differences between the prevalence of loans or loan size. We did not explicitly ask non-migrant households whether they lacked access to trans-local networks or other mobility factors to support their migration.

Consequences of migration

The biggest impacts of migration were perceived to be on labour shortages (50.0% households in Lvea Krang, 40.0% in Popok, and 6.5% in Chamkar Samrong), followed by child welfare-related concerns (50.0% of households in Lvea Krang, 34.7% in Chamkar Samrong, and 13.3% in Popok), and female safety (28.2% households in Chamkar Samrong, 13.3% in Popok, and 7.0% in Lvea Krang). In Lvea Krang, more migrant households had more food than less as a result of migration (25:18), whereas more migrant households in Popok felt they had less food than more (20:13); results were even in Chamkar Samrong (3:3). These findings suggest that migration may not necessarily address climate-induced food insecurity.

Meeting the challenge of food insecurity (defined in the survey as insufficient production to supply consumption) requires different coping strategies. Unsurprisingly, the most commonly used strategy is to buy food. Subsequently, the use of coping strategies depended on location, and whether households had migrants. The predominance of purchasing food or borrowing money to purchase food does not appear to be related to household type, but it does appear that one or other strategy is favoured, which may relate to cash-flow

Table 2 Key reasons for migration and relationships between economic and other reasoning

Location	Food insecurity (FIS; %)	Economic (%)	Economic adjusted for climate (%)	Economic adjusted for climate and FIS (%)	Climate related (%)
Lvea Krang	48.1	81.5	37.0	29.6	51.9
Popok	86.7	86.7	53.3	13.3	46.7
Chamkar Samrong	22	96.0	0.0	0.0	82.2

status or money-lending access of migrant households. In Chamkar Samrong, more migrant households purchased food although for significantly fewer months than non-migrant households ($p = 0.027$), and significantly more migrant households borrowed money to purchase food more often ($p = 0.006$). Combined, households in Lvea Krang employed the greatest diversity of coping strategies, although there were no significant differences on an individual household level between any two communities or household status groupings. Thus, it is likely that households have different levels of access to or preference for particular strategies that addressed their food insecurity.

Lastly, we compared differences in the timing for employing coping strategies to address food insecurity. We choose to exclude Chamkar Samrong from data presentation, given the lower diversity of coping strategies used, and low inter-monthly variation in the percentage of households using different strategies. This can be explained by the context of Chamkar Samrong, near the provincial capital, and therefore with more diverse livelihoods and lower reliance on agriculture. In workshops (see Jacobson and Nguon 2016), village and community leaders identified large differences in wealth and access to land, which would explain food security and financial differences identified in Table 3.

Figure 3a, b demonstrate inter-monthly trends in the prevalence of different strategies used to address food insecurity in Lvea Krang and Popok. A clear trend in use of strategies to address food insecurity (peaking mid wet season) is evident. For Lvea Krang, money borrowing and asset selling peak prior to the onset of peak food insecurity, while purchasing food and using famine foods peak during peak insecurity, and limiting women's access peaks afterwards—perhaps as a last resort strategy. In Popok, the peaks in limiting women's access and migration occur before peak food insecurity, and other strategies occur in step with peak food insecurity. The timing of migration in Lvea Krang suggests that migrants (mostly male) are at home to prepare soils for rice planting, therefore reducing some labour costs. Although they are absent for rice harvest (November/December), this tends to be conducted by

women anyway (Sumner et al. 2017). The timing of migration in Popok appears just prior to peak food insecurity. Thus, it may be being used as a strategy to limit food insecurity impacts; migration peaks at the time of peak rice planting, which may explain lower migration rates and why families with migrants observed increased food insecurity. The choices of coping strategies are affected by access to them, but also to other factors affecting sensitivity to food insecurity. In our context, seasonal volatility in core food stuff prices (i.e. rice) is low—around 10%—and therefore unlikely to have high impacts. While many NGOs are working on various development issues in these communities, direct food aid is minimal and only occurs after disasters such as floods (Unpublished FAO Vulnerability Impact Assessment). While seasonality in 'pull' factors may explain migration timing, likely work sources at migrant destinations are not particularly seasonal, as explained in the "Methods" section. Thus, the timing of migration can influence its subsequent impacts and therefore its effectiveness as a strategy to address climate change.

Discussion

The aim of this article was to understand the relationships between climate change, migration, and food security. Our results identified clear trends towards drying in NW Cambodia, but with variation across districts. Migration affected between a quarter and a half of households surveyed, predominantly driven by climate-related factors, resulting in labour shortages and welfare issues, and coinciding with significantly higher rates of food insecurity. Analyses of food insecurity coping strategies indicate that migration timing is affecting food production systems.

Studies show that climate variations have a significant but non-linear impact on crop yields (Chang 2002). Climate uncertainty is clearly evident in NDVI data variation both between years and between locations. Analysis of historical and projected temperature and rainfall data of Cambodia found that annual mean temperature has increased by 0.8 since

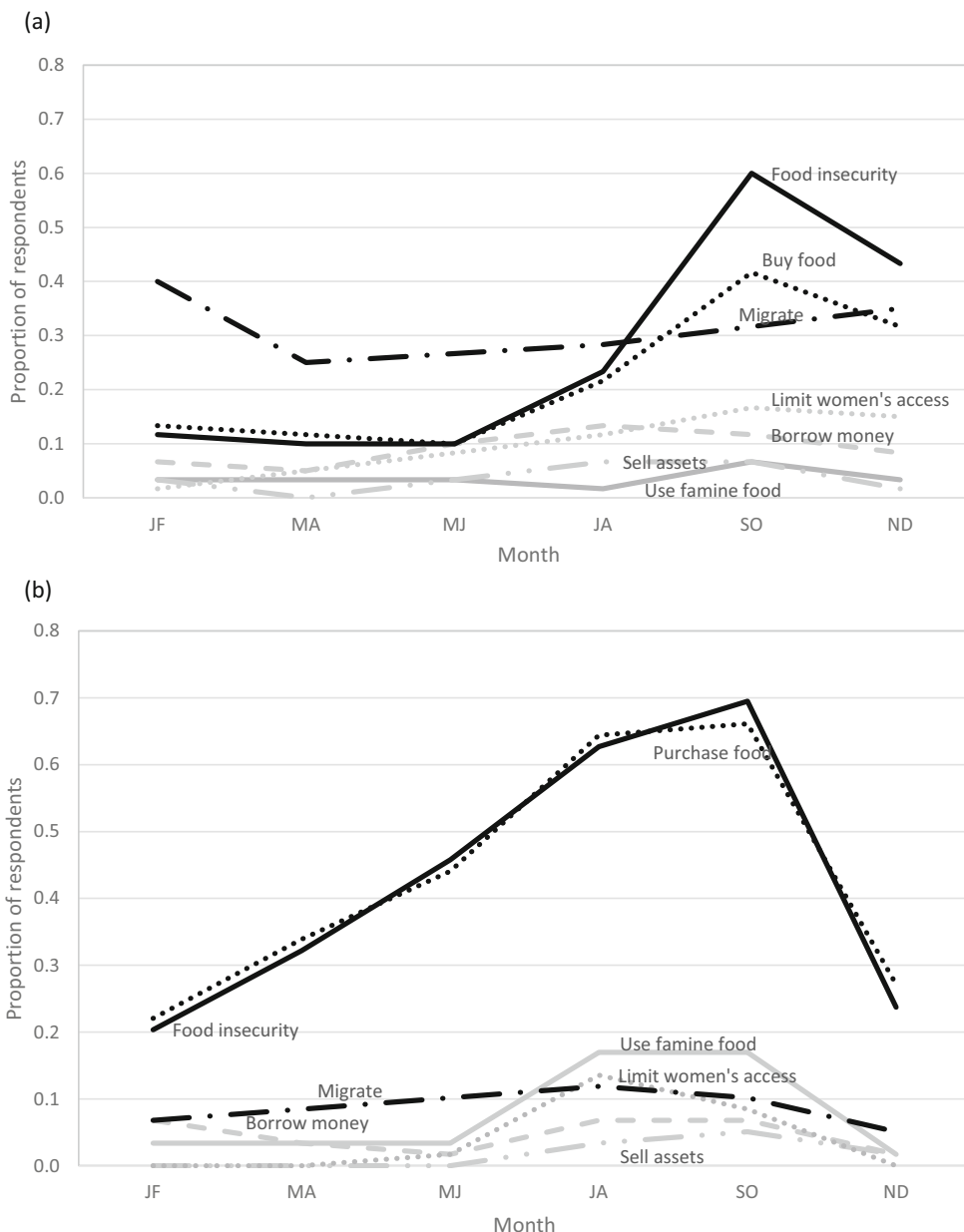
Table 3 Households adopting different coping strategies to address food insecurity (%) - shading indicates non-migrant households

Location	Food insecurity ^a	Harvest immature crops	Use famine foods	Buy food	Borrow money to purchase food	Sell stock	Limit women's access to food
Lvea Krang	59.3 (3.3)	29.6	18.5	70.4	25.9	22.2	29.6
	48.4 (2.2)	18.1	6.1	45.5	27.2	6.1	18.2
Popok	26.7 (4.7)	< 10	40.0	66.7	33.3	< 10	13.3
	25.0 (4.6)	< 10	15.9	77.3	25.0	< 10	13.6
Chamkar	31.1 (1.4)	< 10	< 10	100	13.0 ^b	< 10	< 10
Samrong	5.5 (0.2)	< 10	< 10	98.0 ^b	0	< 10	< 10

^a Defined as harvest running short of consumption needs, measured in number of households, and average months (in brackets)

^b Statistically significant differences in the number of months at $p < 0.05$, placement against household category signals increased use of coping strategy

Fig. 3 Coping strategies applied on a monthly basis. Figure **a** is Lvea Krang and **b** is Popok



1950 and rainfall is decreasing at the rate of 0.184% per year. These changes suggest that there will be a higher chance of failure in agricultural predictions and planning practices in future. Thus, adaptation strategies that address climate change are likely to be dependent on perceived risk; when uncertainty exists, strategies such as migration may be seen as a mechanism to balance economic losses.

Migration causes and consequences

Our analyses attempt to untangle climate and economic drivers of migration. While migrants were sometimes from larger households, the combination of food insecurity and induced labour shortages indicates that these family members

do not represent ‘spare labour’ who migrate to diversify economic risk, as reported in Thailand, Kenya, and Malawi (Ng’ang’a et al. 2016; Suckall et al. 2016; Sakdapolrak et al. 2014). Migrants in this study are ‘displaced’ (Black et al. 2011b; Geddes et al. 2012), providing remittances that address food insecurity and debt.

Climate-related impacts such as bad harvest and agricultural and natural disasters that induce food insecurity and debt explained between two-thirds and all of economic reasons for migration, making ‘climate-related’ factors a key migration driver. While the links between food insecurity and climate change are clear, food insecurity is also affected by skills, knowledge, and assets that enable households to mitigate the impacts of a changing climate on production. The decision for

a household member to migrate in any 1 year is unlikely to be limited to just the previous year's production activity. It may be related to older accumulated debt, not readily identified as 'climate-related', or a combination of older and newer problems that cause an economic tipping point to be crossed, resulting in the decision to migrate. In some cases, respondents may identify with a primary reasoning (e.g. lack of money, or food insecurity), but not what led to that situation (e.g. climate or other causes), nor the cumulative effect of climate on other stressors, nor longitudinal cumulative impacts of climate divers. Alternative research methods, for example analyses of landlessness or debt (e.g. Maltoni 2007), face the same problem. Further disaggregation of reasons for migration could be possible with a much larger sample size, increasing statistical power. However, it will still be difficult to separate cumulative and longitudinal relationships between debt and climate. What we have achieved in our analysis is to separate pure financial reasons for migration from those that relate to climate change impacts on existing livelihoods, and we have identified that climate-related factors are the single biggest driver.

Migration rates identified in our study were higher than the figures reported elsewhere (Kingdom of Cambodia 2012; Bylander and Hamilton 2015), but they were similar to those reported from bordering Laos (Manivong et al. 2014). The variation between locations most likely reflects ease of access to the Thai border, 1.5 h from both Lvea Krang and Chamkar Samrong, and until the recent¹ permeability of this border, where 90% of migrants are reportedly irregular (Maltoni 2007). Migration is not permanent, making migration labour a displaced rather than missing family and community resource. However, this negates consideration of gender-related impacts resulting from predominantly male migrants, i.e. a lack of younger, fitter men to fulfil gender-related roles (Sumner et al. 2017) of land preparation, crop and seed selection, and fertiliser and herbicide application. Thus, migration represents a loss of critical labour from communities that risks exacerbating the effect of climate change rather than remedying it.

Remittances offer a potential means to address loss of labour from a community and ensure that migration is adaptive in the long term. Migrant remittances were only 27–73% of that reported elsewhere (Kingdom of Cambodia 2012), but may go some way towards overcoming a loss of labour associated with displaced migrants. However, reported remittances (\$307–834pa) are unlikely to be sufficient to cover labour costs (\$292 per ha in 2012 (Van Wensveen et al. 2016), and average agriculture holding size of 2–3 ha (Kingdom of Cambodia 2013)). As OECD (2017) note, in 2014, 40% of

remittances are used to pay debt. Thus, migrant displacement would need to avoid critical production events to ensure that migration is an adaptive rather than maladaptive strategy.

Patterns of migration across the year are important given that they influence the ability of a community to avoid impacts on critical production events. In Popok, the co-occurrence of peak migration and rice planting activities explains why migration failed to reduce food insecurity, whereas migration at these times of year in Lvea Krang was at a trough (albeit at a higher rate than in Popok), reducing food insecurity in just over a half of households sampled. The implications for livelihood development are significant, especially given the gendered roles that occur within agriculture production (ADB 2015). The timing of and gender biases in migration affect the labour pool availability for alternative crops. Further, gender shifts resulting from migration have implications for the delivery of agriculture extension services, including the accessibility of these services by generally less literate women (ADB 2015). For migration to be considered adaptive, implications on socio-demographics and subsequent ramifications need to be considered.

A lack of relationship between household food insecurity and purchasing food as a coping strategy, and between the diversity of strategies used by any one household and its status as a migrant or not migrant household, suggest households are using coping strategies that they either have access to or prefer. These choices likely depend on cash-flow status, access to money lenders, the ability to repay loans, or ownership of stock (for sale). Ad-hoc discussions with community members indicate that the use of famine foods (e.g. a traditional wild yam that grows on fallow land) is at least in part cultural, with some families avoiding these foods because of their association with the famine during the Khmer Rouge. That is to say, the choice of coping strategy may be psychological, associated with an individual's or family's previous experiences of trauma. Other studies (e.g. Craven and Gartaula 2015) identify cultured patterns of coping strategy, e.g. migrants were perceived as richer, a perception formed by food-purchasing behaviours, and an activity that resulted in livelihoods shifts away from agriculture—a lower social status activity. This simply shifted livelihood risks from climate, to geopolitical (i.e. seasonal migration schemes in New Zealand and Australia) rather than diversifying livelihood strategies to minimise risk sensitivity. Climate-induced shocks and stresses that accentuate food insecurity could therefore also unevenly affect community resilience, through changes in social status in addition to community wellbeing (e.g. negative impacts we reported on children and women's security). Thus, if migration is to be adaptive, sensitivity to seasonal food insecurity and social status must also be addressed in a culturally sensitive way.

¹ In 2017, as this article was being drafted, the Thai government toughened its stance on irregular (undocumented) Cambodian migrants, establishing mass repatriation centres.

Implications for adaptation

Williams et al. (2016) argues that climate change adaptation has often missed the dual goal of adaptation and poverty reduction. From our analyses and discussion thus far, it is clear that (1) communities are at or below the economic threshold at which migration is ‘survival’ oriented; (2) the climate is becoming increasingly unpredictable, increasing exposure to economic risk; (3) climate is the most significant driver of migration; (4) the gendered and temporal nature of migration is causing socio-demographic shifts in remaining communities that impact on food insecurity; and (5) sensitivity to food insecurity is increased due to (a) gendered roles in agriculture, (b) the gendered nature of agriculture extension, and (c) cultural implications of adaptation activities that reduce exposure sensitivity. Climate change appears to be holding households in a cycle of food insecurity and migration. Addressing these issues requires consideration of adaptive capacity.

A simple response to food insecurity, long-term drying, and more variable rainfall (as evidenced in our NDVI analysis) is to promote irrigation to improve productivity (Wensveen and Roth 2016). Irrigation requires significant infrastructure development, usually incorporates a user pays element, requires co-operation between community for the opening and closing of canals, and requires electricity to operate pumps. This comes at a cost that is likely to be prohibitive for families without the ability to even feed themselves, or alternatively, it could be borne by further restricting women’s access to food or increasing debt.

A second solution is to improve climate resilience of crops to ensure productivity. However, this alone does not adequately address women’s role differences that may be limiting labour availability (see Sumner et al. 2017), or the fact that women are less literate, and have less access to extension services, markets, and technology (ADB 2015). Migration may also compound the intersections between gender and other factors (e.g. economic status) that affect livelihood outcomes and adaptation to climate change. As Carr and Thompson (2014) argue, a richer woman may have more in common with a richer man than she does with a poorer woman. Livelihood adaptation strategies require greater attention to the intersections of marginalisation, vulnerability and poverty if they are to succeed, given that attention to health, education, water, and credit access may have more impact on food insecurity than direct efforts to increase agricultural productivity (Bene and Friend 2011).

To ensure that migration is not maladaptive over the longer term, peak wet season food insecurity needs to be addressed. Migration clearly ought to be considered as part of livelihood development. Solutions are required for migrant households to develop alternative livelihoods that (1) are climatically sustainable, (2) address food shortages, (3) are less labour intensive or closer to home (to address welfare impacts of

migration), and (4) can be utilised during periods of peak migration, such as secondary crops of mung-beans after rice yield, or vegetable crops. The costs of shifting livelihoods (such as skills, equipment, fertiliser, land, etc.) must be understood so as not to worsen household’s economic viability. Co-operative schemes, such as rice or chicken banks, are often seen as a mechanism for the introduction of new livelihood options. The long-term success of different co-operative models in Cambodia has not yet been explored. Co-operatives face further constraints in Cambodia because of their association with the Khmer Rouge. Improved understanding of cultural and gendered perspectives, including adaptation constraints and opportunities, are therefore critical to building effective long-term adaptation strategies that build resilience (Carr and Thompson 2014).

Conclusions

This article aimed to build understanding about the interactions between climate change, food security, and migration in order to design effective adaptation strategies for rural Cambodia. As far as we are aware, this is the first such analysis of its type at the community scale. We identified a clear pattern of climate-reinforced poverty trap, whereby climate-related changes affect food insecurity, leading to subsequent migration that does not necessarily alleviate food insecurity, but leads to a range of social consequences. Our remote sensing analysis suggests that 2015 was not a particularly ‘abnormal’ year. How climate variation manifests in cumulative inter-annual impacts remains unknown. As stands, migration appears survivalist at best and may, given climate projections, prove itself to be maladaptive response to climate change. Much greater concerted attention is needed to address the nexus between poverty and climate adaptation, including longitudinal understanding about the interactions between climate, debt, and food security.

Our unique approach to conducting coping strategy analysis in conjunction with migration analysis demonstrates the multi-faceted nature of vulnerability, and the importance of understanding combinations of characteristics associated with migrant households to design effective adaptation strategies. The socio-demographic of rural Cambodian communities is clearly changing because of climate-induced migration. Thus, adaptation that focusses on climate resilience agriculture to shift communities above the survival threshold may mask the need for adaptation strategy and pathway analysis that addresses intersectional vulnerabilities associated with gender, class, family size, and cultural considerations. Differentiated adaptation strategies could avoid maladaptive pathways over the long term, and ensure migration does not remain a poverty trap.

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Compliance with ethical standards

This research complies with ethical standards as informed consent was gained from all participants.

Conflict of interest The authors declare that they have no conflict of interest.

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