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# How does perception at multiple levels influence collective action in the commons? The case of *Mikania micrantha* in Chitwan, Nepal

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ABSTRACT

Collective action has played a vital role in managing common pool resources in numerous global contexts. This article explores the factors affecting collective action related to the removal of the mile-a-minute weed (*Mikania micrantha*, referred to as Mikania), an invasive plant, in community forests in the buffer zone region around Chitwan National Park in Chitwan, Nepal. Few studies have combined larger sample size quantitative data with greater generalizability and nuanced, qualitative data to explore what factors influence collective action or focused on how perception of the issue at multiple levels affects outcomes. This research employs household and community forest management survey data from 21 community forests in and near the buffer zone of Chitwan National Park in Nepal. Our multilevel econometric analyses, including an analysis examining geographic space using eigenvectors, investigate what influences local people's participation in Mikania removal and we contextualize the findings with case-study interview data. Our results indicate that reliance on community forest resources, perception of the issue, and neighborhood sizes influence are influential factors in their participation in Mikania removal. The implications of these findings are discussed in the context of increasing the effectiveness of Mikania removal efforts and influencing collective action in relation to other global human-environment issues.


## 1. Introduction

In contrast to popular imagery of mountainous terrains, Nepal is one of the most diverse countries (both geographically and culturally) in the world. Historically, Nepal has often been isolated from outside influence due to the surrounding terrain along borders shared by China and India and is one of very few nations in the region never colonized by the British Empire (Bohara et al., 2006). Geographically, the country consists of five physiographic regions including the High Himalayas in the north, the High Mountains, the Middle Mountains (sometime referred to as the mid-hills or middle hills), the Siwalik, and the sub-tropical Terai in the south. The sundry rivers, mountains, forests, and other features made traveling between these regions challenging in the past and often difficult in the present. As a result, the Nepalese people have developed many different sub-cultures and ways to interact with the environment. The varied climates of each region shape this biodiverse nation and house numerous endangered plant and animal species (Nepal and Weber, 1993). For over two decades, community forestry has been an integral part of improving and maintaining the ecological conditions of the forests in the mid-hills, with mixed success in the Terai (Acharya, 2002; Adhikari et al., 2007). Recently, community forest user groups in the Terai have confronted managing their forests located around the border of Chitwan National Park (the "buffer zone") in the face of a rapidly spreading invasive plant species, known informally as lahare banmara (in Nepali) or the mile-a-minute weed (in English) and scientifically as *Mikania micrantha* (hereafter referred to as Mikania).

As a type of forest governance, community forestry attempts to decentralize forest resource management from national level government by transferring most use and management rights to local forest user groups (Barsimantov, 2010; Lama and Buchy, 2002). It has been argued that decentralizing resource management may lead to increased possibilities for collective action to manage resources more sustainably. In Nepal, community forestry appeared in 1978 when the national government issued the first set of regulations intended to legitimize this form of governance (The Panchayat Forest and Panchayat Protected Forest Rules and Regulations of 1978). With promulgation of the Forest Management Act (1993), management rights were formally transferred to local user groups. Although there have been setbacks (especially during political turmoil in the early 2000's, see Gilmour, 2003), the community

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forestry program in Nepal has been considered one of the most successful in the world, particularly in the middle hills region (Nagendra, 2002; Timsina, 2003). However, the success of community forestry in the Terai is more debatable (Anderson et al., 2015; Schusser et al., 2016) and even in the mid-hills, poorer households are less likely to hold leadership roles in community forestry (Yadav et al., 2015). When community forestry was implemented in the Terai, some of the forests were retained by the national government to be protected as national forests. A portion of the remainder of the unprotected forests was given to local communities to manage. However, the condition of the forests transferred to community forest user groups to manage was significantly poorer than that of the forests remaining under national protection. Protected forest lands have generally been found to have a higher level of biodiversity and plant mass (Nagendra, 2002). When evaluating the success of community forestry in the Terai, the initial historical conditions of the forests transferred to local user groups must be considered. Overall, the community forestry program can be considered successful in the Terai on the basis of forest health, as there is evidence that resource conditions have improved in multiple cases (Nagendra, 2002), but its outcomes related to equity and relinquishing of technocratic control by the national government are more debatable (Nightingale, 2005; Ojha, 2006; Tinker, 1994). Given this tension in the literature, there is room to contribute to understanding the outcomes of community forestry in the Terai and what influences those outcomes, especially in the context of recent attempts to manage Mikania to reduce its impact on forest resources.

Our contribution is to demonstrate how a multilevel approach spanning both community and household levels can examine how an ecological, and potentially economic, shock to a social-ecological system impacts multiple stakeholders and the potential for collective action to respond to this shock. In our model, we assess variables at the household and community forest levels (see Section 2 "model development"). Our approach combines independent, representative data sources from community forest management committees and households living in the areas served by the community forests in Chitwan, Nepal, but our method is broadly generalizable to other settings in which multiple levels of stakeholders encounter rapid, destructive change.

### 1.1. *Mikania micrantha*

Mikania is a vine species that both grows and reproduces rapidly. Mikania is native to South America and is believed to have been intentionally transferred from India and the Pacific Islands around the 1940s for use as a cover crop for airfields (IUCN, 2005). It was additionally utilized by soldiers in India during World War II as a type of camouflage (IUCN, 2005). From its initial introduction, Mikania quickly spread to warm, humid places in Asia (including parts of China, India, and Nepal) and North America (including parts of the southeastern United States). Yang et al. (2005) noted that Mikania is one of the top 100 invasive plant threats in the world. As a creeping vine, it climbs small trees and covers grasses, often depriving them of sunlight and smothering them to death (Siwakoti, 2008). Mikania reproduces vegetatively from stems and via seed dispersal, with one plant able to disperse up to 40,000 seeds per year (Yang et al., 2005).

There are a variety of methods that people use to remove Mikania, including pulling (mechanical removal), uprooting, cutting, burning, chemical herbicides, and the use of a pathogenic rust fungi (Ellison et al., 2007). The success of these methods depends on both the biology of Mikania and the social context. For example, burning can further aid seed dispersal (Murphy et al., 2013). Mikania also reproduces vegetatively, where the plant can reproduce when a stem is placed in moist soil. Thus, local collection and transport of natural resources, such as grasses covered in Mikania, results in unintentional Mikania spread. These factors combined have made Mikania extremely difficult to eradicate after it has invaded an area.

In addition to the negative impact Mikania has had on Chitwan's ecosystem (Ram, 2008), Mikania also appears to be an important economic and livelihood issue. Considering the impact of Mikania on rural livelihoods in Chitwan, household surveys have provided evidence that Mikania disproportionately affects forest-dependent households (Rai and Rai, 2013). The longer it remains in the forest, the greater the perceived impacts become and in absence of a plan to successfully remove it, households feel they have been forced to find uses for it (Rai and Rai, 2013), despite the fact that Mikania is a nuisance to most households (Rai and Scarborough, 2014). Further, because Mikania covers grasses that many households collect for agricultural purposes (e.g. to feed livestock or use as livestock bedding), individuals have increased the time spent collecting forest resources, making people more vulnerable to human-wildlife conflicts (Sullivan et al., 2015).

In the past five years there has been news coverage from international and local media on the Mikania issue, primarily focusing on its impact on the vulnerable (previously endangered) one horned rhinoceros' habitat. In 2010, the BBC published a short report on Mikania in collaboration with a local reporter. The report contained excerpts of an interview with the then chief warden of Chitwan National Park and explored the impact of Mikania on the park's ecosystems (Khadka, 2010), including the fact that Mikania had spread to cover over 20% of the park. Mikania has become a well-known issue in the region and successfully managing Mikania to reduce or remove its presence has the potential to improve conditions for both humans and the remainder of the environment.

### 1.2. *Mikania as a collective action problem*

The case of Mikania removal presents a social dilemma, defined as a situation where acting in the benefit of a group puts an individual at a disadvantage unless everyone acts in the interest of the group. In these cases, an individual's return is always greater than an individual's share of a group return. Social dilemmas present a collective action problem. In such a case, collective action may lead to the best outcome for the group, but not the best outcome for an individual unless everyone chooses the action most individually advantageous. Everyone acting to maximize individual benefits causes everyone involved to lose as the tragedy of the commons plays out (Ostrom, 2005, p. 37). A large and diverse body of literature explores the situations and reasons individuals choose to act in the interest of the group when a rational actor would act in their own self-interest (Vanni, 2014). Removing Mikania takes an investment of time and physical and mental effort. Alternatively, opting to ignore the plant's presence and collect resources not impacted by it (i.e., free riding off of someone else's efforts to manage it) reduces the personal costs involved with collecting forest resources.

The model presented in this article explores what factors may impact local people's participation in collective action. Our approach is informed by previous analyses but expands the focus to multiple spatial scales by exploring people's perceptions at both household and community forest levels, and examining the influence of neighborhood size. This study assesses the following questions: What factors affect collective action regarding Mikania removal in Chitwan community forests? Does perception of Mikania as a threat, assessed at household and community forest governance levels, play a role in an individual's decision to participate in its removal?

#### 1.2.1. *What is collective action? Many definitions with common ground*

Collective action as a concept has been adopted by a wide variety of social science disciplines, ranging from psychology to political science, to research and explain actions taken by a group to achieve a specific outcome. In terms of natural resource management, including forestry, collective action at its core includes a group of people acting voluntarily in the name of a common purpose or shared interest to achieve a desired outcome (Meinzen-Dick et al., 2004). People do not always have to act simultaneously in a group to engage in collective action; sometimes a representative of a group may act on the group's behalf. Further, collective action can occur at multiple scales and include both top-down or bottom-up actions, with Davies et al. (2004) labeling the former "coordination" and the latter "cooperation". In the context of community forestry, collective action has been key to caring for forest resources through activities such as forest cleaning and tree replanting (Sekher, 2001). In commons research more broadly, collective action has been found to be important to the sustainable governance of common pool resource systems globally (Ostrom et al., 1994; Vanni, 2014).

#### 1.2.2. What influences collective action?

A variety of factors have been found to influence collective action in common pool resource management situations, including governance structure, group size, distance from nearest market, resource scarcity, age, income, land holding, distance from the relevant resource, caste, gender, and education (Adhikari, 2005; Araral, 2009). Although past work has illuminated the role of "formal" institutions (such as rules) in community forestry outcomes, the role of informal institutions (such as social norms) remains less understood (Lachapelle et al., 2004). Systematic analyses of the factors influencing collective action are needed to begin to understand what drives collective action across different natural resource management contexts (Araral, 2009).

The role of social, economic, and institutional heterogeneity in collective action is not always clear or straightforward (Varughese and Ostrom, 2001). Heterogeneity in this context relates to the variation of social and institutional factors that could influence a group's ability to achieve a commonly held goal. It is therefore possible that variation in formal and informal institutions could pose a challenge to successfully engaging group members in collective action to manage common pool resources (Kant, 2000; Ostrom, 2005). Variation in local institutions with respect to sociodemographics, like caste, ethnicity, race, or gender, influences community forestry operations, including who benefits from or participates in collective resource management (Adhikari, 2005). Some scholars assert that sociodemographic heterogeneity undermines collective action, but there are few empirical studies that assess how this variation affects the individual decision to collectively act (Ostrom, 2005; Varughese and Ostrom, 2001). We believe exploring social variation explicitly, without focusing only on the obstacles heterogeneity poses, can expose which factors may influence collective action.

Previous econometric analyses have assessed collective action as a dependent variable, but usually as an analysis of free riding in a collective action problem rather than directly estimating household or individual participation in a specific collective action (outside of participation in small-scale resource management programs like forestry or irrigation (e.g. Chun, 2014; Coulibaly-Lingani et al., 2011)). Araral (2009) used a binary variable to represent irrigation systems that were either under government control or fully managed by local users, finding that collective action was impacted by governance structure, as well as resource scarcity, resource user group size, and farm size. There is a need for further research in this area to understand if similar factors influence collective action across distinct natural resource management cases. In part due to lack of data, few empirical quantitative analyses of collective action have been conducted (Poteete and Ostrom, 2004). The majority of commons research has been qualitative work, but there are calls to conduct more systematic, comparative, and quantitative research (Agrawal and Chhatre, 2006). Such studies would complement existing qualitative studies, provide a different perspective, and increase the replicability of findings.

### 1.3. Geographic space and collective action: the role of neighborhoods

Previous work exploring geographic space has most often conceptualized space in terms of place, region, or networks (e.g. Bosco, 2001; Hedström, 1994; Miller, 1992; Murdoch and Marsden, 1995; Paasi, 2002). Such work has largely concluded that space influences the formation of collective action for political and other purposes and that the role of space in collective action requires further investigation (Newman, 2008). Within the realm of geographic space, neighborhoods influence many social dynamics, including informal institutions such as social norms (Leventhal and Brooks-Gunn, 2000; Lochner et al., 2003; Sampson et al., 2002). Neighborhoods are nested units within larger communities, and are defined variously from administrative boundaries (such as census blocks in the U.S. census) to local networks (Sampson et al., 2002). Despite the potential importance of the role of neighborhoods in influencing participation in collective action, and the significance of neighborhoods to social groups in Nepal, research linking collective action and neighborhoods has seldom been conducted.

### 1.4. Our analysis

Previous work has argued that research related to collective action must move towards a diagnostic approach that considers local context in institutional and governance arrangements in social-ecological systems (Araral, 2009; Ostrom, 2007). Furthermore, it is likely that one optimal set of rules and norms does not apply in all contexts. To address these issues, in-depth, qualitative research is needed to combine contextual knowledge to inform the interpretation of quantitative (e.g., statistical) analyses (Agrawal and Chhatre, 2006).

Collective action has been assessed at the association/resource group level by multiple studies. However, multilevel models of collective action that incorporate household data are less common (Tesfaye et al., 2012), as well as models that consider the influences of visible or invisible neighborhoods. By using both household and community forest level data, we provide a nuanced picture of factors that influence collective action. This study builds on previous statistical analysis of the factors influencing collective action (Araral, 2009) and explores additional factors related to perception of the situation, in this case whether Mikania is viewed as harmful. Analysis of the factors that impact collective action across a variety of contexts will help to address numerous pressing global environmental problems connected to common pool resources (Esty and Moffa, 2012; Ostrom, 2010).

## 2. Model development: variables that may influence participation in Mikania removal

### 2.1. Household level variables

We conducted a standardized survey with 1041 households total across 21 community forest catchment areas that border Chitwan National Park in which households are eligible to join a community forest (see Methods for survey details).

#### 2.1.1. Participation in collective removal of Mikania growing in or near a community forest

The dependent variable in our model concerns whether a household participates in Mikania removal either with a group or both individually and with a group. In our study site, each community forest is governed by a locally elected governance committee. No organized effort to remove Mikania had been implemented by the community forest governance committees at the time of our study. Some committees paid individuals or, rarely, paid specific user groups within their community forest to remove Mikania. As such, almost all group removal efforts are coordinated by households (both community forest members and nonmembers) living in the area. In interviews with individuals from five case studies from our 21 community forests (case studies were selected to capture the range of resources available in each group, including monetary), we found that household members who participated in Mikania removal self-organized annual removal efforts with their neighbors. Our survey question captured all such self-organized group removal efforts.

Here, we present a unique conceptualization of a dependent variable in an econometric model of collective action. Other models have assessed free riding (monetary and labor) in collective resource management (Araral, 2009; Ito, 2012) whereas we explicitly model who is engaging in collective Mikania removal (i.e. who is not free riding).

#### 2.1.2. Community forest membership

Most households in the buffer zone region of Chitwan National Park who use forest resources are members of an established community forest user group. Two-thirds of our survey sample (690/1041) are community forest members. There are several reasons households in our sample are not members, including (from most to least common): living too far from the forest, disagreement with management policies, and fees being too high (fewer than 3% of respondents reported that fees were a barrier to entry). The household survey dataset analyzed here includes both buffer zone community forest members and non-members in an effort to accurately assess the factors influencing collective action among all households in the region. Previous work has discovered that community forest members in Chitwan tend to be more reliant on forest resources than non-members (Sullivan et al., 2015) and we hypothesize that households that depend on forest resources are more likely to participate in collective action. Thus, we anticipate that community forest membership will be an important predictor of participation in Mikania removal efforts. Other variables included represent different dimensions of reliance on forest resources.

#### 2.1.3. Ethnicity/caste and income

Caste plays a complex role in community forestry outcomes in Nepal. Generally, traditionally disadvantaged indigenous ethnic groups in Nepal are less likely to receive benefits from community forestry operations (Adhikari et al., 2004; Gilmour et al., 2004). However, this relationship is not always straightforward, as there are policies regarding ethnicity and caste that benefit certain groups and influence activity in certain regions in Nepal (Nightingale, 2011). In the case of collective action problems, indigenous groups often lead and participate in efforts to collectively solve them, but may not receive the same benefits as other privileged groups (Graner, 1997). Given this uncertainty in the literature, we included caste composition among the 21 community forests to explore if and how they influence participation in Mikania removal efforts.

Progress has been made in understanding the influence of income on numerous social outcomes (e.g. Heathcote et al., 2010). However, there is no consensus on how household income influences reliance on natural resources. Some studies have found that households with lower levels of income are more dependent on natural resources and receive greater absolute benefits from the resources (Shackleton and Shackleton, 2006; Turner et al., 2007). Others have discovered that higher income households are better positioned to take advantage of some forest resources (Acharya, 2005).

#### 2.1.4. Household size

Larger household size could influence action related to Mikania management, either prohibitively due the time required to conduct other important household activities, or positively because more household members are available to distribute the labor involved in Mikania removal (Fischer and Qaim, 2012; Poteete and Ostrom, 2004). As household size increases, people who are already reliant on natural resources may maintain or increase their resource use. However, household size may also be irrelevant, i.e. households that are dependent on natural resources may be just as likely to engage in resource management and Mikania removal whether they are large or small.

#### 2.1.5. Farming activity

Over 80% of households in our survey sample in Chitwan farm in some capacity for a portion of their food and income. Farming households in general are especially reliant on forest resources to maintain farm animals and crops. However, since so many households in Chitwan are agricultural to some extent, it is possible there may not be enough variation in our case study to accurately discern its impact.

#### 2.1.6. Household distance to community forest

A household's distance to the nearest community forest was the most frequently cited barrier to membership by survey respondents. Households that are farther from community forests are less able to access the resources they may need. As distance from the resource influences access to forest resources (Sullivan et al., 2015) and a household's ability to utilize them, it is likely households that are farther from the resource will be less able to participate in Mikania removal.

#### 2.1.7. Household perception of Mikania as harmful to households and forests

Individual level perception of collective action problems can alter whether an individual is interested in participating in collective action to solve an issue. In a study of participatory forest management in Ethiopia, perception of planting success rates (seedling survival) was found to strongly influence intentions and attitudes towards participating in collective tree planting efforts (Tesfaye et al., 2012). Similarly, individual perception of risk has been found to influence willingness to engage in collective action to solve climate change and related environmental problems in other case studies (Lubell, 2002; Lubell et al., 2007; Stoutenborough et al., 2015), with higher perceived individual risk correlated with a greater potential of participating in collective action.

### 2.2. Community forest level variables

The community forest level variables are from a standardized survey that was conducted with the 21 community forest management committees (more information on the management survey is also presented in the methods section).

#### 2.2.1. Community forest age and income

We explore the influence of community forest governance committee income on collective action outcomes (CF_income in Table 1). This information is recorded in Nepal rupees from community forest management survey responses and then divided by 1,000,000 to ensure the variable is on a similar scale compared to the other variable ranges (the exchange rate of rupees to dollars is small: 1,000,000 rupees is approximately 15,000 USD as of this writing). Like household income, the impact of community forest management level income is unclear. Increased income should allow for community forest governance committees to provide their members with additional resources and attract members (Graner, 1997), but how such income is invested is not always clear to members (Sullivan et al., 2015). A second variable measuring the number of years since a community forest was established is included to detect the impact of the maturity of the community forest governance on collective action. Community forests that were founded earlier are likely to possess increased social capital including monetary resources and connections with non-government organizations and other community forest governance committees. The resources available to members can influence their investment in the resource and age influences governance structure (Araral, 2009).

#### 2.2.2. Community forest governance committee perception of Mikania as harmful

Perception of issues by different actors within polycentric governance systems can influence actions among other actors (Ostrom, 2010). In this case, we believe the perception of Mikania as harmful to local households or forest health by members of community forest management will impact the household decision to remove Mikania.

**Table 1**
Variable explanations and summary statistics.

| Variable | Explanation | Type | Mean | S.D. | Min | Max | Sum |
|---|---|---|---|---|---|---|---|
| ParticipateCA | Household participation in Mikania removal in a group or as a group and an individual | Dependent variable; Dichotomous; 1 = yes, 0 = no | 0.348 | – | 0 | 1 | 363 |
| CF_member | Is the household a community forest member? | Dichotomous; 1 = member, 0 = non-member | 0.662 | – | 0 | 1 | 690 |
| Ethnicity/caste | Caste of interviewee or head of household | Expanded dummy variable with Bramin as the reference level (ethnicities 2–5 in order[a]) | 0.159 | – | 0 | 1 | 166 |
| | | | 0.126 | – | 0 | 1 | 132 |
| | | | 0.036 | – | 0 | 1 | 38 |
| | | | 0.170 | – | 0 | | 177 |
| Income | Household income past year | Categorical; coded 1 to 7 from under 10,000 rupees to >500.000 rupees | 4.163 | 1.428 | 1 | 7 | |
| HH_size | Number of people in a household | Continuous | 5.280 | 2.240 | 1 | 16 | |
| HH_dist_CF | Distance from house to nearest community forest in km | Continuous | 1.644 | 1.069 | 0.038 | 5.23 | |
| Farm | Does the household farm? | Dichotomous; yes = 1; no = 0 | 0.810 | – | 0 | 1 | |
| Perceive threat | Does the household perceive Mikania as harmful? | Dichotomous; yes = 1; no = 0 | 0.886 | – | 0 | 1 | |
| CF_income | Total income received by governance committee in past year, divided by total member households; in Nepal rupees, divided by 1,000,000 | Continuous | 1.396 | 1.873 | 0.002 | 6.65 | |
| CF_age | Years since community forest was established to present | Continuous | 20.86 | 6.848 | 6 | 35 | |
| CF perceive threat | Does governance committee perceive Mikania as harmful to local households? | Dichotomous; yes = 1; no = 0 | 0.749 | – | 0 | 1 | |

[a] Ethnicities_2: Hill Janajati, 3: Dalit, 4: Newar, 5: Terai Janajati (all ethnicities are coded in reference to the Bramin/Chhetri group, which is considered the highest socioeconomic status group in Nepal (Stash and Hannum, 2001)).

*2.2.3. Geographic space conceptualized via neighborhood size*

Space often plays a key role in social-ecological outcomes (Alessa et al., 2008; Walker et al., 2004). As few previous studies have explored the potential impact of neighborhoods on collective action, we hypothesize that neighborhoods of various sizes may influence a household's participation in collective action (i.e. we hypothesize that some relationships may change as neighborhood size changes).

## 3. Methods

In order to assess the factors influencing collective action, we conducted a multilevel/hierarchical analysis of survey data and interpreted the results in the context of rich, qualitative case study interview data. Multilevel models are useful for data that have a clustered or hierarchical structure. In this case, the data consist of households nested within community forest user groups. Modeling hierarchical data with a single level structure can underestimate standard error and ignore group effects (Steele, 2008). The dependent variable (whether a household participates in Mikania removal efforts) is not continuous, which makes ordinary least squares (OLS) regression problematic because OLS regression produces biased estimators when applied to discrete dependent variables. Thus, we implement a binary logistic regression model, as this allows for analysis with binary dependent variables (Williams, 2006).

We first present the results of the model without considering neighborhood sizes and then present the second analysis incorporating neighborhoods. We then interpret the statistical results in the context of qualitative case study findings. The qualitative data consist of 29 semi-structured interviews conducted in 2014 in five case study community forests. Survey data from 1041 households total in 21 Chitwan buffer zone community forests and survey data from members of the governance committees of all 21 community forests are utilized in the analysis. The household survey sample included a representative sample of each community forest and included demographic information and sections on household farming, livestock and fish farming, household relationships to community forest governance, household relationships to invasive species (including Mikania), ownership of household items, and household consumption. The community forest management survey was conducted with one member of each of the 21 community forest governance committees and included sections on general background information, local plant species and their uses, governance committee activities, rules and enforcement, user groups, and perceptions of community forest issues. The household and governance committee surveys were conducted in 2014 and the respective response rates were 98.6 and 100%.

*3.1. Model specification*

Building off of factors found to be significant in impacting collective action, the model specification is below.

$$\begin{aligned} participateCA_{ij} = \beta_0 + \beta_1 CFmember_{ij} + \beta_2 ethnicity_{ij} + \beta_3 income_{ij} \\ + \beta_4 HHsize_{ij} + \beta_5 HHdistCF_{ij} + \beta_6 farm_{ij} \\ + \beta_7 perceiveMikaniaThreat_{ij} + \beta_8 Cfage_j \\ + \beta_9 CFincome_j + \beta_{10} CFperceiveThreat_j + u_{0j} \end{aligned}$$

The above specification is a random effects hierarchical linear model for every individual $i$ in community forest $j$ where $u_{0j}$ represents these random effects at the community forest user group level. Because the dependent variable is binary, a logistic model where the dependent variable represents the log odds ratio (or logit) is appropriate and estimated (Snijders and Berkhof, 2008). In any type of logistic regression, the primary assumptions involve sample size, outliers, and multicolinearity (Menard, 2002). Sample sizes for logistic regression should take into consideration the number of predictors used; small samples with a large number of predictors can produce problems. Outliers and multicolinearity were checked for in each independent variable; extreme outliers were not present and issues with correlation between independent variables are discussed below. Analyses were conducted in R (version 3.1.2) using the lme4 package (version 1.1-9).

*3.2. Using eigenvectors to explore the impact of neighborhoods*

Households within a neighborhood may share some common features, and such spatial association or spatial autocorrelation (i.e., within-neighborhood similarity or homogeneity) may lead to biased regression coefficients. In order to understand how geographic factors may influence our chosen factors' ability to explain collective action, we employ eigenvectors as spatial filters to remove the potential bias (An et al., 2016; Chun and Griffith, 2011; Griffith, 2000). Eigenvectors were calculated for a set of predetermined neighborhood sizes according to latitude and longitude coordinates collected from each survey respondent's household location. These coordinates allowed us to map households into neighborhoods and accordingly calculate eigenvectors for the 10, 20, 30, 40, and 50 nearest neighbors for each household. One hundred eigenvectors were calculated for each household at each neighborhood size. We used the top ten eigenvectors (i.e., the ones with the highest eigenvalues) at each neighborhood size in five models (one for each neighborhood size) in our second analysis. The full details of the eigenvalue calculation are available in An (2016).

## 4. Results

We find that belonging to a community forest and perceiving Mikania as a threat are significantly positively correlated with participating in Mikania removal at the household level and identifying as Newar decreases the likelihood of participating in Mikania removal (Table 2). In Chitwan, Newar individuals are relatively rare as Newar is an indigenous group that has historically been prominent further north, in the valley outside of Kathmandu (Nepal's capital and largest city). The Newar have a higher average socio-economic status compared to other indigenous groups in Nepal and traditionally have held professions outside of agriculture. They are thus typically less reliant on forest resources (in Chitwan, Newars do tend to have a higher median annual income than Dalit, Terai Janajati, or Hill Janajati peoples). Additionally, at the community forest level, the governance committee's perception of Mikania as harmful is significantly negatively correlated with a household's decision to participate in Mikania removal. Household income, belonging to several indigenous groups or being Dalit, household size, household distance to the forest, and farming were not significant influences on Mikania removal in the final aspatial model. However, alone, household distance to the forest and farming were both significant influences on participation in Mikania removal (Table 3). These variables are correlated with community forest membership and the moderate multicollinearity renders them insignificant in the final model including all variables.

When spatial filtering is incorporated, we find that the majority of our results hold at the smaller neighborhood sizes, but that some relationships change as the neighborhood size increases (Table 4). We discuss the implications of our findings next.

## 5. Discussion

Here, we first consider our results without spatial filtering and later discuss the impact of incorporating spatial filters.

### *5.1. Perceptions of collective action problems influence participation*

Our results show that when households perceive the presence of Mikania to be harmful, they are more likely to participate in Mikania removal. This finding has implications for other collective action problems, as it suggests that people need to perceive the situation as personally harmful before working to collectively solve it or cease free riding off of others' efforts (Lubell, 2002). This analysis is not the first to suggest the importance of individual, community, or household perception of issues in solving collective action problems. However, we believe our quantitative, multilevel exploration in the context of an increasingly important global human-environment issue, the spread of invasive species, is an important contribution and confirms the need for further study in this area.

**Table 2**
Model results with all variables (no spatial filtering).

| Level 1 (HH) | Estimate (standard error) |
|---|---|
| Intercept | −1.385059** (0.614937) |
| CF_member | 0.813201*** (0.164079) |
| Ethnicity_2 (Hill Janajati) | −0.004459 (0.212095) |
| Ethnicity_3 (Dalit) | 0.172931 (0.231685) |
| Ethnicity_4 (Newar) | −0.993093** (0.475196) |
| Ethnicity_5 (Terai Janajati) | 0.062026 (0.242313) |
| Income | 0.029869 (0.050848) |
| HH_size | 0.017616 (0.032006) |
| HH_dist_CF | −0.144327 (0.116428) |
| Farm | 0.232520 (0.199788) |
| Perceive_mikania_threat | 0.861755*** (0.255881) |
| Level 2 (CF) | |
| CF_AGE | −0.012219 (0.017111) |
| CF_income | −0.057189 (0.075865) |
| CF_perceive_threat | −0.597360* (0.318123) |

N = 1041 HH, 21 CF.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.0001$.

**Table 3**
Model results with single variable estimates.

| Model (predictor) | Estimate (standard error) |
|---|---|
| Model 1 (CF member) | 0.8793*** (0.1574) |
| Model 2 (ethnicity) | Ethnicity_2: −0.1353 (0.2027); ethnicity_3: 0.0788 (0.2233); ethnicity_4: −1.0785** (0.4660); ethnicity_5: 0.1383 (0.2353) |
| Model 3 (income) | 0.0415 (0.0478) |
| Model 4 (HH size) | 0.0477 (0.0300) |
| Model 5 (HH distance forest) | −0.1800* (0.1042) |
| Model 6 (farm) | 0.4904*** (0.1877) |
| Model 7 (perceive Mikania threat) | 0.8775*** (0.2494) |
| Model 8 (CF income) | −0.0320 (0.0709) |
| Model 9 (CF age) | −0.0191 (0.0183) |
| Model 10 (CF perceive threat) | −0.2793* (0.3014) |

N = 1041 HH, 21 CF.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.0001$.

### *5.2. Reliance on natural resources is an indicator of engaging in collective action*

Supporting our hypothesis, households that are more dependent on community forest resources (i.e. those belonging to a community forest) are more likely to engage in Mikania removal. This finding supports the idea that community forest membership is an important indicator of having a personal stake in community forest resources. Farming, which is another measure of reliance on community forest resources, was significantly correlated with participating in Mikania removal on its own, but was highly correlated with being a community forest member and was thus insignificant when all variables were included (see Tables 2 and 3). The correlation between resource dependence via farming and membership aligns with our expectations. Although a few Chitwan residents who may need forest resources are not community forest user group members (see "community forest membership" section for a discussion of barriers to entry), most households dependent on forest resources are members. We did not directly measure differences between member benefits, but it should be noted that whether or not all members receive the same benefits is questionable (Bhattarai and Ojha, 2001). The relationship between reliance on forest resources and participation in Mikania removal is linked to the perception of the problem as harmful or benign because people with no stake in the impacted resource (those who do not need to use it) are unlikely to perceive Mikania as an issue that impacts them and needs to be addressed. In other words, there is little perceived risk in their choice to ignore Mikania.

### *5.3. Unpacking the influence of perception at the community forest level*

We were surprised to find that perception of Mikania as harmful by a community forest governance committee is significantly negatively correlated with a household's participation in Mikania removal. We hypothesized community forest governance committee concern about Mikania might foster a setting where more individual households are aware of Mikania as harmful and choose to participate in removal

**Table 4**
Results of spatial filtering models.

| Model ➔ | No spatial | NBH 10 | HBH 20 | NBH 30 | NBH 40 | NBH 50 |
|---|---|---|---|---|---|---|
| *Level 1 (HH)* | | | | | | |
| Intercept | −1.385059$^{**}$ (0.614937) | −1.8627$^{**}$ (0.79675) | −1.6117$^{**}$ (0.614022) | −1.76583$^{**}$ (0.555294) | −1.5442$^{**}$ (0.565005) | −1.5526$^{**}$ (0.571927) |
| CF_member | 0.813201$^{***}$ (0.164079) | 0.80440$^{***}$ (0.16825) | 0.77331$^{***}$ (0.165543) | 0.81208$^{***}$ (0.164652) | 0.8146$^{***}$ (0.164825) | 0.8332$^{***}$ (0.165212) |
| Ethnicity_2 (Hill Janajati) | −0.004459 (0.212095) | −0.02685 (0.21929) | −0.029390 (0.2136) | −0.101710 (0.211223) | −0.075044 (0.211663) | −0.077877 (0.211145) |
| Ethnicity_3 (Dalit) | 0.172931 (0.231685) | 0.30331 (0.25158) | 0.175541 (0.234244) | 0.174156 (0.232780) | 0.253085 (0.234320) | 0.327081 (0.238692) |
| Ethnicity_4 (Newar) | −0.993093$^{**}$ (0.475196) | −0.90141$^{**}$ (0.48807) | −0.93893$^{**}$ (0.478861) | −0.94097$^{**}$ (0.482376) | −0.9165$^{**}$ (0.478808) | −0.8664$^{**}$ (0.482824) |
| Ethnicity_5 (Terai Janajati) | 0.062026 (0.242313) | 0.10685 (0.2712) | 0.216007 (0.232012) | 0.305682 (0.23917) | 0.273732 (0.240665) | 0.271159 (0.237680) |
| Income | 0.029869 (0.050848) | 0.02750 (0.05165) | 0.026267 (0.050938) | 0.014879 (0.051204) | 0.017177 (0.051276) | 0.018064 (0.051340) |
| HH_size | 0.017616 (0.032006) | 0.01910 (0.03259) | 0.021240 (0.032479) | 0.020089 (0.032338) | 0.018595 (0.032309) | 0.018612 (0.032252) |
| HH_dist_CF | −0.144327 (0.116428) | **−0.37557$^{**}$ (0.16224)** | −0.152223 (0.138599) | −0.240010 (0.139012) | **−0.3104$^{**}$ (0.144388)** | −0.241587 (0.150712) |
| Farm | 0.232520 (0.199788) | 0.21845 (0.20421) | 0.249721 (0.201226) | 0.220717 (0.203623) | 0.251899 (0.202856) | 0.254372 (0.202335) |
| Perceive_mikania_threat | 0.861755$^{***}$ (0.255881) | 0.87822$^{***}$ (0.26066) | 0.85084$^{***}$ (0.256024) | 0.82325$^{***}$ (0.257383) | 0.8135$^{***}$ (0.257638) | 0.8223$^{***}$ (0.258346) |
| *Level 2 (CF)* | | | | | | |
| CF_AGE | −0.012219 (0.017111) | 0.02428 (0.02931) | −0.001696 (0.015828) | 0.006029 (0.015092) | 0.004768 (0.015155) | 0.005126 (0.015207) |
| CF_income | −0.057189 (0.075865) | 0.14540 (0.13262) | −0.007164 (0.088989) | **−0.4018$^{***}$ (0.107376)** | **−0.372$^{***}$ (0.102935)** | **−0.3969$^{***}$ (0.104871)** |
| CF_perceive_threat | −0.597360$^{*}$ (0.318123) | −0.87605$^{**}$ (0.42155) | −0.726559$^{*}$ (0.295239) | **0.354947 (0.306564)** | **0.159632 (0.279693)** | **0.008384 (0.289957)** |
| *Eigenvectors* | | | | | | |
| Eigen1 | | −5.04185 (14.18957) | −2.168690 (3.217738) | −6.949163 (3.566353) | 4.525912 (5.697266) | 49.8083$^{***}$ (14.365982) |
| Eigen2 | | 9.80318 (14.86248) | 3.712529 (3.677870) | −19.542$^{***}$ (5.004745) | −25.92$^{***}$ (6.252023) | 110.795$^{***}$ (28.413786) |
| Eigen3 | | −5.19743 (3.80379) | −9.14711$^{**}$ (3.774720) | 15.7656$^{***}$ (4.411047) | 24.922$^{***}$ (6.817462) | −3.354607 (5.874289) |
| Eigen4 | | −4.15245 (3.83952) | 2.106211 (4.729554) | 31.4282$^{**}$ (13.538901) | 37.171$^{***}$ (9.308714) | 7.884616 (6.584032) |
| Eigen5 | | −1.16079 (3.95069) | −0.174514 (4.179696) | 43.4101$^{***}$ (16.038039) | −2.745146 (5.358389) | −14.663$^{***}$ (4.656964) |
| Eigen6 | | 12.85628$^{**}$ (6.34740) | −6.995553 (4.172717) | 6.209407 (4.717159) | −39.54$^{***}$ (14.82324) | −13.005$^{***}$ (4.252553) |
| Eigen7 | | 10.06661$^{**}$ (4.52989) | −23.02401 (12.4325) | −13.774$^{***}$ (4.989631) | 10.067689 (6.254897) | 1.858194 (5.419257) |
| Eigen8 | | 12.89399$^{**}$ (5.87581) | −20.35677 (16.96564) | 28.1619$^{***}$ (8.254470) | −15.22334 (9.217449) | 8.2293$^{***}$ (3.910026) |
| Eigen9 | | −3.91785 (5.11391) | −4.677092 (5.970647) | −6.072814 (3.486686) | −6.495850 (7.688246) | −12.446$^{***}$ (4.502668) |
| Eigen10 | | −1.34642 (4.33239) | −2.108502 (10.12355) | −5.291565 (4.414548) | 2.440397 (2.515810) | −9.018$^{***}$ (4.367460) |

N = 1041 HH, 21 CF; Standard error in parentheses.
Values that have changed in significance are bolded and NBH = neighborhood.
$^{*}$ $p < 0.05$.
$^{**}$ $p < 0.01$.
$^{***}$ $p < 0.0000$.

efforts. However, awareness of a problem does not always lead to action (e.g., Kollmuss and Agyeman, 2002), and in this case, governance committees that perceive Mikania as harmful do not always share this information with their members. In the fieldwork conducted in 2014 in five case-study community forests, interviewees distrusted some of their community forest governance committees and officials from nearby Chitwan National Park. With this contextualized knowledge, it makes sense that even if governance committee members were diligent in informing community forest members of their perceptions of the Mikania issue, members are unlikely to trust all of the information they receive from their governance committees. This distrust may influence how members perceive issues and households may subsequently choose to take actions that differ from their governance committee's recommendations. Further, research has showed that perceptions of collective action problems among actors in polycentric governance systems can influence collective actions taken by actors at different levels (Andersson and Ostrom, 2008; Ostrom, 2010). Another possibility is that the forest governance committee's perceptions are a consequence of their member's lack of action. In other words, governance committees may perceive Mikania as a threat when they realize that their own members are not engaging in efforts to reduce Mikania. We are unable to discern what is the mechanism that differentially links members' and governance committees' perceptions to households' Mikania removal, but our multilevel approach highlights the importance of measuring perceptions at these two different levels. As our results show, it is unwise to assume that perceptions of governance actors is identical to – or is merely a reflection of – household perceptions.

### *5.4. Top-down versus bottom-up approaches to solving collective action problems*

Our model shows that perception of Mikania as harmful by households influences household participation in efforts to prevent and reduce its spread. This linkage between the perception of an issue as personally harmful (personal risk) and engaging in collective action in an effort to solve it is relevant to other critical global environmental issues, such as mitigating or adapting to climate change (Lubell et al., 2007). Even in cases where Mikania is not viewed as harmful by the community forest governance committee, households that perceive Mikania as personally harmful are more likely to participate in removal efforts. In the case of collective action problems where households or individuals do not rely on or buy into the impacted resource or system, top-down perception of the situation may be important. For example, in the case of climate change, even in cases where bottom-up collective action has been absent, strong action from government in a top-down approach can have success. Following from these results, many studies have found support for a blended top-down and bottom-up approach to solving collective action problems (Anderson and Grewell, 1999; Ansari et al., 2013; Fujisawa et al., 2015; Green et al., 2014; Pahl-Wostl, 2009).

According to our survey data, 35% of surveyed households are participating in Mikania removal efforts. Thus, the initiative for engaging in collective action to remove Mikania exists for some Chitwan households but the methods people choose to remove Mikania (such as burning) unfortunately sometimes work against their goals, likely spreading the plant and its seeds further (Murphy et al., 2013). It is possible that the nature of the human-environment problem determines what type of collective action will be proficient in solving it. For example, some problems may be most effectively solved with collective action initiated from the top down, while others will have better results organizing from the bottom up (Ostrom et al., 1994). However, it may also be the case that most collective action problems can be solved with a bottom-up approach if the people involved are given access to the appropriate tools, knowledge, and resources. Most research on the commons supports the assertion that, under particular social-ecological conditions, individuals can self-organize to solve a wide variety of human-environment issues (Ito, 2012; Meinzen-Dick et al., 2000; Tang, 1992). For instance, if a local non-government organization provided information on the impacts of Mikania on forest health and livelihoods to households in Chitwan, it is possible more households would perceive Mikania as harmful and choose to engage in removal efforts.

### 5.5. Incorporating spatial filtering: the role of neighborhoods

Overall, the addition of spatial filtering did not impact the factors influencing collective action at smaller neighborhood sizes, but some of the relationships in our model changed at larger spatial scales. It is important to keep in mind that the survey data utilized in our analysis represents a subset of the households within a given community forest. Therefore, the spatial influences we find in our analysis are likely to be amplified in the actual neighborhoods containing more households. Based on fieldwork in Chitwan, the smaller neighborhood scale (10 or 20 households in our analysis) is the most accurate representation of how people regularly interact and define their neighbors. Because the spatial filtering via inclusion of the eigenvectors largely impacts the model results at the larger neighborhood sizes, we conclude that space is more influential as neighborhood size increases. We focus on interpreting two collective action relationships that neighborhoods influenced: community forest level income and the perception of Mikania as a threat by a community forest governance committee (both community forest level variables in our analysis).

#### 5.5.1. Community forest level income

Our model results indicate that spatial influences operate at the larger neighborhood sizes on community forest level income (the total income available to each community forest governance committee; see Table 1). At neighborhood sizes of 30, 40, and 50 households, the higher the community forest's income, the less likely a household will participate in Mikania management (this is a change from insignificant to significant and negative). Additionally, some studies have found that households with higher incomes are less likely to be community forest members (Malla, 2000). The relationship between income and membership appears to be capturing a livelihood transition in Chitwan, where people with higher incomes have begun to transition away from dependence on the forest resources to other, non-agricultural livelihoods. Households belonging to wealthier community forests that provide a wider variety of resources to their members (such as non-agricultural, skills based trainings and workshops) may be less likely to participate in collective action because they may be shifting away from dependence on the community forest resources. Capturing the influence of geographic space in terms of neighborhood size is important not only for statistical reasons (e.g., an insignificant coefficient becomes significant or vice visa), but also for theoretical and practical reasons. This kind of spatial effect only exists on some variables, which might indicate that collective action may be affected by factors operating at more than one spatial scale or neighborhood size. Thus, our results suggest that one-size-fits-all management interventions and solutions may be ineffective as solutions are likely to have different effects at different levels (e.g. households, neighborhoods, community forest user groups).

#### 5.5.2. Perception of Mikania as a threat at the community forest level

Spatial filtering additionally impacts the relationship between collective action and the perception of Mikania as a threat by community forest governance committees. Perception at the community forest level shifts from significantly influencing collective action at the smaller neighborhood scale, to being insignificant at larger neighborhood sizes (30, 40, and 50 households); in other words, this relationship breaks down at larger spatial scales. Numerous households belonging to Chitwan community forest user groups report distrusting either their governance committee members or Chitwan National Park officials and such households are often spatially close (i.e. neighbors) and share their immediate neighbors' or family members' opinions (Sullivan et al., 2015). This outcome results in heterogeneous clusters of opinions within a given community forest user group. When these heterogeneous clusters are grouped together in a larger spatial unit, the relationship between perception and household participation in collective action breaks down.

As space appears to alter some factors' influences on collective action at larger neighborhood sizes, i.e., sizes that are more representative of the community forest spatial extent, there are implications for local stakeholders who are interested in encouraging or influencing Mikania management efforts. For instance, if community forest governance committee members wish to improve the reception of their opinions regarding Mikania and management options in areas where household distrust is present, our analysis indicates that engagement at the sub-community forest level is important to overcome these issues. Opinions of community forest governance committees are clustered and influential in collective action decisions in smaller neighborhoods, of which there are many in a given community forest area. Targeting efforts to disseminate information about Mikania management at a smaller scale may improve trust and have a greater impact than distributing information only at the community forest user group level.

Our comparative analysis incorporating spatial filtering is one way to examine the influence of space on collective action and is a point of departure for future efforts. There are many potential ways to strengthen or expand this analysis in future work, including exploring different conceptualizations of neighborhoods and investigating other ways of defining space, such as through different network analyses.

## 6. Conclusions

Understanding what influences collective action at multiple scales in the management of natural resources is broadly important, with the potential to aid groups in overcoming barriers to engaging in collective action to solve global human-environment issues. Our multi-scale, mixed methods approach, which uses both quantitative and qualitative information, is a first step in uncovering important details related to the multiple factors that influence collective action. In particular, our results highlight the importance of studying the precursors of collective action at multiple scales, including both actors at the individual or household level as well as the larger governance institutions in which they are embedded.

Agrawal (2001, 2014) notes that the search for general principles to govern the commons and common pool resources, that apply in all cases, is often fruitless and time consuming. It has been argued that researchers should instead focus on comparative analyses and statistical interpretations of data to achieve an "empirically relevant theory of the commons" (Agrawal, 2001, p.1649). We believe statistical analyses, large sample size comparative studies, and consideration of neighborhood impact can contribute to both of these goals. Statistical analyses can assist researchers in identifying overarching patterns in collective action as they accumulate over time, while simultaneously providing insight into unique systems and local problems (Gibson et al., 2005; Pagdee et al., 2006). Using a statistical model, this research compared collective action across 21 community forests, contextualized the findings with qualitative data, and explored how these findings fit into a larger discussion regarding the importance of rigorously understanding what influences collective action.

Certain types of human-environment problems are suited to be effectively solved with different types of collective action (i.e. top-down versus bottom-up), and solutions will be context and community specific (Ostrom, 2007; Ostrom et al., 1999; Taylor and Van Grieken, 2015). Overall, patterns in the factors that influence collective action from both from empirical statistical studies and large N comparative studies can move researchers towards identifying generalizable commonalities. This broader understanding may contribute to designing situations and institutions to encourage collective action at different levels, such as households, neighborhoods, or entire community forest user groups. In other words, if researchers understand what is likely to influence collective action in different global contexts, at different scales, they can help empower communities to solve critical issues as the community views them. If individuals must perceive environmental issues as posing personal risk to attempt to solve them (Lubell, 2002; Lubell et al., 2007; Stoutenborough et al., 2015), researchers need to understand when and why people perceive some human-environment issues as personally risky while others are interpreted through a distant, detached perspective. These findings call for a greater number of rigorous studies that investigate perception of collective action problems as personally harmful or benign to individuals. With this knowledge, researchers will be able to further explore (1) if perception is universally important in all collective action problems and (2) the differences between individuals who perceive these problems as posing personal risk.

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