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Declining Large-Cardamom Production Systems in the Sikkim Himalayas

Climate Change Impacts, Agroeconomic Potential, and Revival Strategies

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Large cardamom (*Amomum subulatum*) is an economically valuable, ecologically adaptive, and agro-climatically suitable perennial cash crop grown under tree shade in the eastern Himalayas. In Sikkim, India, the focus of this study, large-cardamom

production peaked early in the 21st century, making India the largest producer in the world, but dropped sharply after 2004; Nepal is now the largest producer. This crop is an important part of the local economy, contributing on average 29.2% of the income of households participating in this study. Farmers and extension agencies have worked to reverse its decline since 2007, and thus, there is a steady increase in production and production area. After reviewing the literature, we carried out extensive field research in 6 locations in Sikkim in 2011–2013 to investigate the causes of this decline and measures being undertaken to reverse it, using a combination of rapid rural

appraisal, participatory rural appraisal, structured questionnaire, and field sampling techniques. Study participants attributed the decline in large-cardamom farming to 4 broad types of drivers: biological, socioeconomic, institutional/governance-related, and environmental/climate-change-related. Altered seasons, erratic or scanty rainfall, prolonged dry spells, temperature increase, soil moisture loss, and increasing instances of diseases and pests were prominent factors of climate change in the study region. Multistakeholder analysis revealed that development and implementation of people-centered policy that duly recognizes local knowledge, development of disease-free planting materials, training, subsidies, and improved irrigation facilities are central to improving cardamom farming and building socioeconomic and ecological resilience.

Keywords: Large cardamom; climate change impacts; household economy; revival strategy; Sikkim Himalayas.

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Introduction

Large cardamom (*Amomum subulatum*) is the most important perennial cash crop in the eastern Himalayan region (Sharma et al 2000). It is used as a spice or condiment, flavoring agent, and preventive and curative agent for sore throats, lung congestion, digestive disorders, and pulmonary tuberculosis in Unani and Ayurvedic medicine (Sharma et al 2009). This crop is believed to have been first domesticated by the indigenous Lepcha tribe and then by other communities such as the Bhutias and Nepalīs of Sikkim, and was later passed on to the neighboring district of Darjeeling in India and to southern Bhutan and eastern Nepal (Sharma et al 2000; Sharma et al 2007). The agroclimatic range of large cardamom farming is similar to the altitudinal range of Himalayan alder (*Alnus nepalensis*) and mixed agroforestry species, which are widely used as shade trees (Sharma et al 1994). India is now the second largest producer and the

largest exporter of large cardamom, contributing about 37% of the world's production, while Nepal is the world's largest producer with a share of more than 53% (Sharma et al 2009; Singh and Pothula 2013; Subedi et al 2014).

Sikkim contributes up to 88% of India's production of large cardamom. The cash income earned from this crop in Sikkim increased from US\$ 1.9 million in 1975 to US\$ 13.8 million in 2005 and as high as US\$ 50 million in 2010 (Sharma et al 2009; Sharma and Acharya 2013; Partap et al 2014). Sikkim is also fast becoming known in India for its organic farming, and organic large cardamom has a potentially strong international market (FSADD and HCDD 2012). For more than a decade now (2004 onwards), however, more than 60% of the cardamom plantations in Sikkim have become barely productive, resulting in a tremendous decline in cultivated area as well as total production in the state (DESME 2002, 2005, 2006, 2010; HCCDD 2010). The income of marginal and cardamom-dependent farmers in the eastern Himalayan

region has dramatically declined, jeopardizing their livelihoods (Srinivasa 2006; Sharma et al 2009; Singh and Pothula 2013). This decline is an example of the long-term environmental and ecological implications of farming that relies on a single cash crop, the impact on farmers' livelihoods, and the unprecedented challenges for sustaining and improving production capacity.

This study had 4 goals: (1) investigate the current status of large-cardamom farming and its contribution to the livelihoods of marginal farmers, (2) assess local actors' perceptions of the decline in large-cardamom production area and productivity, (3) analyze crop cycle, adaptive management, and revival strategy for cardamom-based farming systems, and (4) analyze the challenges and opportunities emerging from different drivers of change.

Materials and methods

Study sites

The households that participated in the study belong to 6 study sites based on their dependence on large cardamom-based traditional farming systems (Figure 1; Table 1). Of the 88 households participating in the study, 22 were at Sumik-Khamdong, 14 at Sang-Martam, and 14 at Dhanbari-Tumin, in the East District of Sikkim; 14 at Lingee-Sokpay in the South District; and 12 each at Hee-Pechreak and Hee-Martam in the West District. These sites are situated between 1000–2200 masl and have large cardamom as their principal cash crop. They are located within larger cardamom-growing areas (also shown in Figure 1) that range in elevation from 500 to 2300 m; agroclimatic conditions vary with elevation.

Farmers have, in addition to large-cardamom farming, adopted innovative intercropping of farm trees (fodder, fuelwood, timber, or fruit trees), other fodder crops, and beans, and in some areas grow a wider range of crops (pulses, oilseeds, soybeans, yams, and vegetables), multipurpose agroforestry species, and medicinal plants (Sharma et al 2016). Annual rainfall averages 3500 mm across the study sites, 2000–4000 mm in the higher elevations, and 1000–2000 mm in the lower elevations (Rahman et al 2012; Seetharaman 2012; Tambe et al 2012). The study sites are mostly southwest facing; slopes range from 10 to 30°. The upper reaches of Dhanbari-Tumin, Sumik-Khamdong, and Lingee-Sokpay experience occasional snowfall, hailstorms, and frost during winter.

Methods

We carried out an extensive secondary literature survey, and data on the 6 study sites were pooled to estimate the large-cardamom plantation area, production, and productivity (DESME 2002, 2005, 2006, 2010; HCCDD 2010).

A multistage, stratified sampling technique was followed to select the sample households in the 6 study

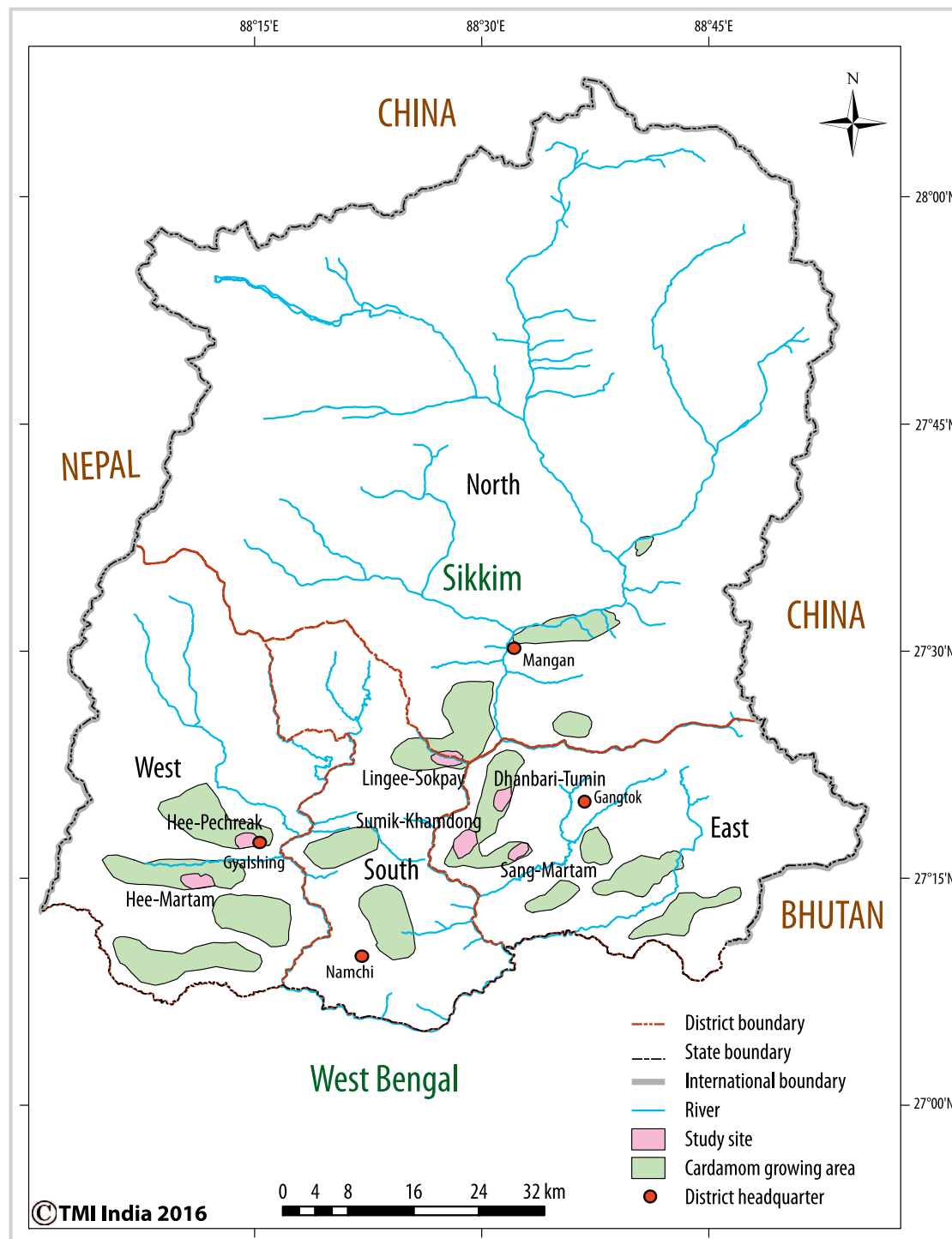
sites. A total of 88 households were selected for detailed study during 2011–2013, representing different ethnic communities, landholding sizes (1.5 to 3 ha), social and economic relationships, and farming practices. The primary livelihood source for all households was traditional large-cardamom-based agriculture. The households were surveyed using structured questionnaires to investigate the range of livelihood options associated with large-cardamom-based farming systems and the contribution of each option to household income, using rapid rural appraisal to obtain scientific evidence through quicker and more cost-effective qualitative techniques that could not be gathered by quantitative research, and participatory rural appraisal for data-gathering by way of participatory mapping, visual sharing techniques, and other self-determined community-based methods (Chambers and Blackburn 1996). Focus group discussions were used together with extensive field sampling and observation to document climate change impacts, traditional management practices, and adaptation strategies for the revival of the system.

Furthermore, 20 key informants—progressive cardamom farmers and *panchayat* (elected representatives of the village, self-government) members from other cardamom-growing areas in Sikkim, academics, large-cardamom scientists, extension and development workers, researchers, and professionals at the policy and planning level—were interviewed regarding their perceptions of the changes in large-cardamom plantation area, total production, and yield per hectare and climate change impacts, as well as existing extension services and the challenges and opportunities associated with cardamom farming.

During participatory rural appraisal/rapid rural appraisal and focus group discussions, respondents were also asked about the incidence of viral diseases (including *chirkey*, *furkey*, *pahenley*, and rhizome rot) and dry spells. Plants infected by *furkey* (bushy dwarf) disease have shorter stems and the spikes become stunted, crop production declines rapidly, and the whole cardamom bush dies within 2 to 3 years. A plant infected by *chirkey* (mosaic streak) produces brownish spots all over the leaves, and in time the entire leaves become brown and eventually dry out. *Pahenley* is a *Phoma* leaf spot disease that rapidly spreads during continuous rain, resulting in severe damage of cardamom bushes. Long dry spells were defined as periods without rainfall lasting from November through April.

Qualitative information collected in the surveys was complemented with information collected during the literature review. Information on competitive marketing and auctions was obtained from the North Eastern Regional Agricultural Marketing Cooperation in Sikkim. Data were collected on the various household income options and the amount of income they provided, demographic features, literacy, ethnic community composition, education level, occupational structure,

FIGURE 1 Study sites and the surrounding large-cardamom growing areas in Sikkim. (Map courtesy of The Mountain Institute, India)



landholdings, cropping patterns, and crop yield. The total yield was converted into monetary value based on current market rates. Each household's total annual cash income from other sources—such as the Mahatma Gandhi

National Rural Employment Guarantee Act (MGNREGA), a 100-day employment scheme of the Government of India (MGNREGA 2005), and other off-farm employment—was also recorded.

TABLE 1 Characteristics of the 6 study sites.^{a)}

Study area	Altitude (m)	Aspect	Slope (°)	Rainfall (mm)	Humidity (%)	Climate events	Ambient air temperature (°C)
East district							
Sumik-Khamdong	1500–1900	West, southwest	15–30	1000–2100	70–98	Hailstorms and frost	10–23
Sang-Martam	1000–1700	West, southwest	10–20	1000–1800	60–90	Hailstorms	13–25
Dhanbari-Tumin	1700–2200	Southwest	10–20	2000–4000	70–99	Frost, snowfall, and erratic rainfall	6–20
South district							
Lingee-Sokpay	1000–2300	East, southwest	15–30	1000–4000	60–99	Snowfall, hailstorms, and erratic rainfall	6–23
West district							
Hee-Pechreak	1400–2000	West, southwest	15–30	1000–2000	70–98	Hailstorms	10–24
Hee-Martam	1200–1800	West, southwest	15–30	1000–2000	70–95	Frost in upper reaches	14–27

^{a)}Data sources for rainfall and humidity calculated from Tambe et al 2012, Rahman et al 2012, Seetharam 2012, and field recordings.

Data analysis

We analyzed the household livelihood options based on empirical socioeconomic, biophysical, and institutional data. The average landholding of the cardamom growers was calculated by adding the total landholdings of the respondents and dividing the sum by the number of households. We used Microsoft Excel for data computation and SPSS version 10 to conduct analysis of variance and regression analysis. The study sites did not vary much with regard to management practices, climate change indicators, diseases, and pest infestations, and thus data were pooled, extrapolated, and interpreted for these factors.

Results

Large-cardamom area and yields

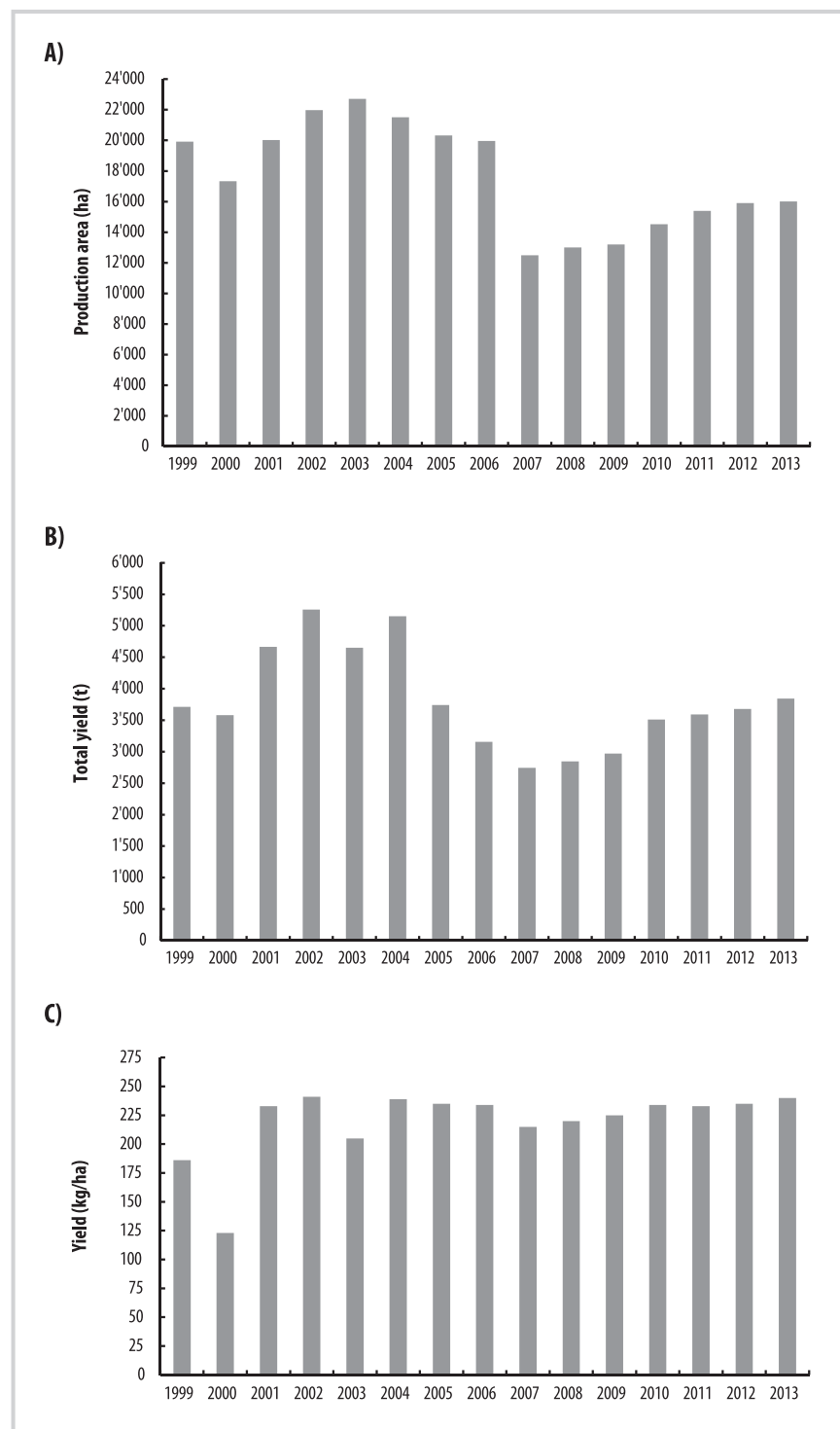
According to the Spices Board of India and the Horticulture and Cash Crops Development Department Government of Sikkim, the total area under large cardamom in Sikkim in 1997 was 26,734 ha. The *plantation area* is the total plantation area under large cardamom, not all of which gives yield. *Production area* is the actual area that provides an agronomic yield on a yearly basis. The actual cardamom production area in 1999 was only 19,912 ha, but increased to 20,023, 21,797, and 22,714 ha in 2001, 2002, and 2003, respectively. As a consequence of long dry spells and disease infestations during 2004–2007, the production area and yield decreased each year, with an especially sharp drop (37%) to 12,500 ha from 2006 to 2007 (Figure 2). Revival strategies were then initiated by improving the management of the farms: application of manures before flowering and after harvesting, irrigation

during dry winter months, uprooting infected plants, and manual management of pests and diseases followed by application of biopesticides. Farmers planted cardamom in new fields, leaving the old plantations fallow, while the Sikkim Government Horticulture and Cash Crops Development Department and Spices Board provided them with incentives for reviving large cardamom. This led to a gradual increase in production area and yield in the next 6 years (Figure 2).

Total production of cardamom in Sikkim has fluctuated (Figure 2). In 2002, Sikkim produced a record large-cardamom yield (almost 5227 metric tonnes [t], up from 3710 t in 1999), and thus India became the largest producer worldwide, accounting for about half of the world's production (SDR 2008). However, with the consistent decline in plantation area after 2004, production declined to 2745 t in 2008, and India dropped to second place, after Nepal. Production gained momentum from 2008 to 2013, owing to increased awareness, farmers' innovations and motivation, and the government's provision of extension services. Accordingly, the total large-cardamom production area in 2013 was about 14% greater than in 2007, with an average production of 3312 t per year. The average cardamom production area increased from 12,500 ha in 2007 to 16,010 ha in 2013.

Large-cardamom yield was very low (average 148 kg ha⁻¹) during the early 1990s, increased a bit later in that decade (average 228 kg ha⁻¹), decreased again during 2006–2007 (average 220–225 kg ha⁻¹), and showed good improvement during 2012–2013 (with 238 kg ha⁻¹) (Figure 2). Linear regression modeling showed a positive correlation between cardamom-yielding area and year for 2007–2013 ($y = 661.64x - 1E+06$, $R^2 = 0.95$, $P < 0.001$).

FIGURE 2 Large-cardamom production in Sikkim. (Data sources: DESME 2002, 2005, 2006, 2010; HCCDD 2010; SOM 2014)



Total production also showed a positive correlation ($P < 0.001$) for data computed from 2007–2013 ($y = 0.287x - 831.49$, $R^2 = 0.94$, $P < 0.001$). This was attributed to the revival strategies that were initiated after 2007 by

cardamom farmers and extension agencies. By 2013 the production area had increased to 16,010 ha, with a total production of 3842 t and yield per ha of 240 kg (SOM 2014).

TABLE 2 Average annual household income (in US\$) and contribution of different income sources.

Income source	Study site						% of total
	Sumik-Khamdong	Sang-Martam	Dhanbari-Tumin	Lingee-Sokpay	Hee-Pechreak	Hee-Martam	
Crops^{a)}	3.04	56.75	138.23	12.17	24.07	24.69	1.38
Large cardamom	508.33	223.61	168.78	1318.19	1035.49	2206.79	29.20
Other cash crops ^{b)}	7.15	205.03	4.64	27.51	22.38	14.81	1.51
Beekeeping	10.52	0.00	0.00	12.57	3.09	0.00	0.14
Livestock	298.28	301.59	461.59	203.76	193.67	854.78	12.37
Services ^{c)} and remittances	1482.32	1583.99	1616.93	952.38	1496.91	2793.21	53.07
Labor under the MGNREGA ^{d)}	104.38	10.32	107.94	39.68	101.85	70.68	2.33
Total	2414.02	2381.29	2498.11	2566.26	2877.46	5964.96	100.00

^{a)}Rice, maize, wheat, millets, and pulses.

^{b)}Orange, ginger, inflorescence of broom grass, and small cash crops such as fruit and vegetables sold on the market.

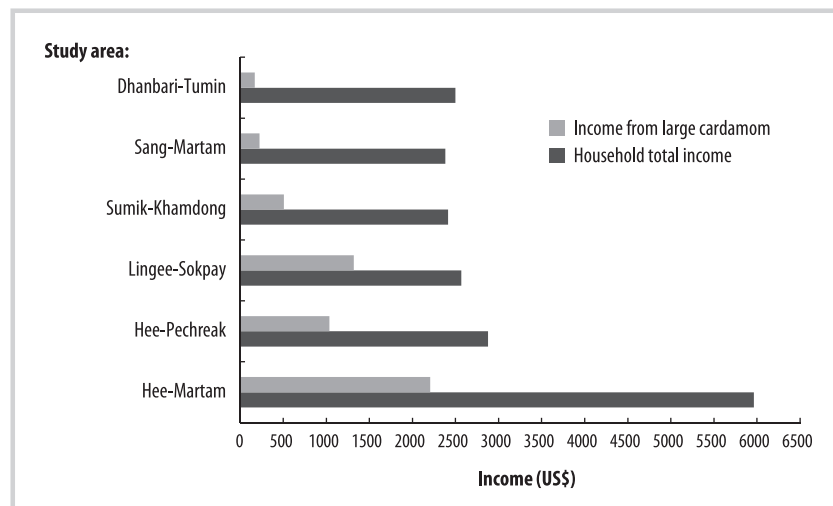
^{c)}Services refer to employment in the government sector, nongovernmental organizations, or in pharmaceutical and hydropower companies.

^{d)}MGNREGA = Mahatma Gandhi National Rural Employment Guarantee Act. Income source calculated in Indian rupees and converted into US\$, 1 US\$ = INR 60.

Economic sustainability of household incomes

Of the 6 major household livelihood sources identified, services and remittances contributed the most to household income (Table 2). Services refer to employment in the government sector, nongovernmental organizations, or in pharmaceutical and hydropower companies. Large cardamom was the second largest contributor (generating on average US\$ 911 per year per household), followed by livestock. The remaining sources of income were crops, other cash crops, beekeeping, and employment under the Mahatma Gandhi National Rural Employment Guarantee Act, which together contributed only 4% of household income.

Annual household income among large-cardamom farmers participating in the study was highest at Hee-Martam, followed by the adjacent village Hee-Pechreak (Table 2), which is credited to the cultivation of the new disease-tolerant and high-yielding local cultivar *Seremna*, supported by income from services and remittances. The farmers raise nurseries of *Seremna* cultivars and supply good quality planting materials to progressive farmers and to the Horticulture and Cash Crops Development Department and Spices Board at Gangtok, Sikkim, to generate cash income. Another effective cultivar is *Dzongu-golsai*, used in Lingee-Sokpay. The contribution of large cardamom to household income was only 7, 9, and 21% in Dhanbari-Tumin, Sang-Martam, and Sumik-Khamdong

FIGURE 3 Contribution of large cardamom to total income in the study sites.

Khamdong, respectively, while in Hee-Pechreak, Hee-Martam, and Lingee-Sokpay it was much higher: 36, 37, and 51%, respectively (Figure 3). The lower earnings in the first 3 villages were due to the lack of good planting material and poor management practices. The contribution of services and remittances was high in Hee-Martam (28.1%), remained within the range of 14–16% in Dhanbari-Tumin, Sang-Martam, and Sumik-Khamdong, while it was low in Lingee-Sokpay, with 9.6%.

Based on yield per hectare and 2014 market prices (US\$ 24 kg⁻¹), the income from large cardamom can be estimated at US\$ 3246–5610 per household. One-way analysis of variance showed significant variation among the range of livelihood options across the 6 study sites ($F_{6,35} = 15.54$, $P < 0.001$). Large-cardamom farming was less labor intensive (using only 10–15% of the total number of farm laborers) than other farming options (85–90%).

Local and improved cultivars

The local farmers in Sikkim grow more than 8 different local cultivars of cardamom developed, tested and practiced in different agroclimatic situations and under different farm management conditions. Of them, 6 varieties are widely grown between 600 and 2300 m throughout Sikkim and some parts of the Darjeeling hills. *Seremna*, a variety developed by the Limboo tribes of Hee-Bermiok, West Sikkim, is a location-specific cultivar that is tolerant to diseases and pests and gives a high yield (300–450 kg ha⁻¹). Another disease-tolerant cultivar that is cultivated widely is *Dzongu-golsai*, developed by the Lepchas of Dzongu, North Sikkim. The local cultivar *Bharlangey* is best suited to the middle and higher altitudes (1500–2000 m) and has a high market value due to its high productivity, large capsule size, good aroma, and characteristic and marketable maroon color. The Indian Cardamom Research Institute of the Spices Board in Gangtok identified the potentially disease-tolerant varieties *Sikkim I* and *Sikkim II* in 2000 on farmers' cardamom farms, but they have not yet scientifically confirmed that these varieties are disease and pest resistant as well as high yielding, and farmers have not yet tested them.

Perceived drivers of cardamom crop decline

Factors that study participants perceived as driving the decline of large-cardamom farming could be grouped into 4 main categories: environmental or climate-related, biological, socioeconomic, and institutional or governance-related (Table 3). The study looked at views expressed by both key informants and cardamom growers.

As many as 85–100% key informants stated that extreme heat or cold, erratic/untimely rainfall, reduction in temporal spread of rainfall, shift in seasons, long dry spells lasting until flowering, drying springs, and

temperature rise were the factors responsible for decline of cardamom. Interestingly, almost 100% cardamom growers consider drying springs or streams in and around plantations as the main factor for decline while 53% further said that it is due to erratic/untimely rainfall, and 63% argued that it was due to long dry spells (Table 3).

Similarly mixed observations were recorded for biological drivers of change. The cardamom growers were very specific regarding factors based on their farm experiences: 77–94% observed emergence of diseases, pests, and insects, decreased number of pollinators, and inadequate pollination due to climatic variations (erratic rainfall) as the major reasons for decline, while 85–100% of key informants consider all of these as the cause of decline. Around 80–100% of key informants perceived weak shade management, absence of good planting material, old and exhausted farms, low soil fertility, and loose soils as contributing to crop decline. In contrast, the majority of cardamom growers (60–89%) did not consider these as major reasons for the decline. Both key informants (100%) and cardamom growers (77–94%) considered diseases and pests and decrease in pollinators as the main reasons for plantation decline. As many as 55–95% key informants said that low soil fertility, loose soil, old farms, weak shade management, and lack of disease-free planting material contributed to the decline, while 95–98% of growers did not consider these reasons for plantation decline. Sixty to 85% of key informants considered socioeconomic factors important in the decline of cardamom farms. In contrast, 84–96% of cardamom growers did not consider socioeconomic factors—family fragmentation, low productivity on farms, and weak farm management—the drivers of decline.

Sixty-five percent of growers considered lack of irrigation facilities a major cause of decline. Fifty-two percent of growers commented on the lack of appropriate policy support, 69% pointed to lack of extension services, and 89% to the lack of training, disease management, and irrigation facilities. Around 65–75% of key informants said that there were issues related to governance that needed to be taken into consideration. Of the 30 key indicators of climate change identified, the key informants and cardamom growers had contradictory responses for 21 factors and provided similar responses on 9 factors.

Diseases and pests

Crop development, plantation management, pest or disease outbreaks, and climate-change-related challenges for cardamom farming are presented in Table 4. Farmers have innovated several climate-smart adaptive measures that increase yield and improve performance of cardamom growth. Six prominent diseases were found to be prevalent in cardamom bushes: leaf streak (*Pestalotiopsis* sp.), fungal disease (*Colletotrichum gloeosporioides*), leaf spot

TABLE 3 Respondents' perceptions of the principal drivers of the decline in large-cardamom farming.

Type of driver	Specific driver	Mentioned by study participants	
		Key informants (n = 20)	Cardamom growers (n = 88)
Environmental or climate-related	Erratic/untimely rainfall	19 (95%)	47 (53%)
	Reduction in even temporal distribution of rainfall	19 (95%)	11 (13%)
	Long dry spells during winter, lasting until flowering	20 (100%)	56 (64%)
	Temperature rise	20 (100%)	30 (34%)
	Air pollution	13 (65%)	6 (7%)
	Frost or hail	12 (60%)	17 (19%)
	Snowfall	11 (55%)	10 (11%)
	Shift in seasons	19 (95%)	11 (13%)
	Extreme heat or cold	17 (85%)	6 (7%)
	Drying springs or streams in and around plantations	19 (95%)	88 (100%)
Biological	<i>Chirkey, furkey</i> , fungal blight, and <i>pahenley</i>	20 (100%)	83 (94%)
	Insect pests	20 (100%)	72 (82%)
	Mammalian pests	16 (80%)	2 (2%)
	Low soil nutrient content or fertility	19 (95%)	4 (5%)
	Loose soil due to alder tree roots	11 (55%)	2 (2%)
	Decreased number of pollinators (due to climate change impacts)	19 (95%)	68 (77%)
	Old and nutrient-exhausted farms	17 (85%)	7 (8%)
	Inadequate pollination	17 (85%)	56 (64%)
	Lack of appropriate shade management	18 (90%)	4 (5%)
	Lack of disease-free planting materials	16 (80%)	17 (19%)
Socioeconomic	Weak farm management	17 (85%)	14 (16%)
	Fragmentation of land ownership	12 (60%)	5 (6%)
	Low crop productivity	17 (85%)	2 (2%)
	Lack of irrigation facilities	14 (70%)	57 (65%)
Institutional or governance-related	Lack of policy support for cardamom farming	14 (70%)	46 (52%)
	Lack of extension services (financial/material support)	12 (60%)	61 (69%)
	Low level of research on mitigating disease problems	15 (75%)	9 (10%)
	Lack of local institutions for growers (cooperatives and farmers' clubs)	15 (75%)	3 (3%)
	Lack of forward and backward linkages	13 (65%)	12 (14%)
	Lack of training in selection of disease-free planting material, growth management of cardamom for increased productivity, technical knowhow for disease management, and irrigation facilities	13 (65%)	78 (90%)

TABLE 4 Annual calendar of large cardamom's growth cycle, management regime, and major farming challenges.

Month	Crop development	Plantation management	Pest outbreaks
Jan.		Removing diseased plants Manuring of bushes Irrigating using sprinklers Monitoring and management of diseases	In some areas, monkeys destroy cardamom bushes and break new spikes
Feb.			
Mar.			
Apr.	Flowering starts, moving from lower to higher altitudes Pollination starts	Replanting/gap filling with healthy suckers Weeding, bush clearing, etc. during flowering and fruiting Developing nurseries Transplanting in new locations Monitoring of the disease	Rodents and birds damage flowers Caterpillars attack leaves Porcupines destroy crops
May			
June	Pollination continues Fruiting starts, moving from lower to higher altitudes Spikes start maturing, beginning at lower altitudes	Harvesting and curing, beginning at lower altitudes Selling during festivals Harvesting in higher altitudes	Civet cats eat the mature capsules, causing heavy loss
July			
Aug.			
Sept.			
Oct.	New spikes start to appear	Monitoring diseased and healthy plants	Monkeys, bears, porcupines, and boars destroy the bushes
Nov.			
Dec.			

TABLE 4 Extended

Month	Disease outbreaks	Climate-related challenges
Jan.	Decay and drying of rhizome due to low soil moisture	Prolonged dry period Hailstones destroy crops Loss of soil moisture Drying of the leaves or even rhizomes due to sunburn
Feb.		
Mar.	Onset of <i>chirkey</i> , <i>furkey</i> , and fungal disease	
Apr.		
May		
June	<i>Collectotrichum</i> blight, phoma leaf spot disease, and leaf streak disease	Erratic (heavy) rainfall causes flower fall or decay Excessive rainfall causes loss of soil fertility; mudslides and landslides occur
July		
Aug.	Incidence of stem borer, capsule borer	
Sept.		
Oct.	Wilting of leaves and spikes due to disease during dry periods; white grub continues to infect rhizomes Some rhizomes infected by fungus dry during winter; leaves and pseudo-stem also dry	Dry period starts, loss of moisture Sunny days burn the cardamom leaves Frost and snowfall destroy crops
Nov.		
Dec.		

disease (*Phoma hedericola*), *furkey* (bushy dwarf), *pahenley* (*Fusarium oxysporus*, *F. solani*), and *chirkey* (mosaic streak) (Table S1). Around 70% of the farmers said that *chirkey* and *furkey* were the only diseases they were somehow able to manage for some years and produce some yield. Soon after, rhizome decay emerged, both *chirkey* and *furkey* also became unmanageable, and entire plantations were damaged. Four insect pests (leaf caterpillar, shoot fly, stem borer, and white grub) and 6 mammalian pests (Himalayan palm civet, crestless porcupine, monkey,

Himalayan black bear, wild boar, and barking deer) were causing damage to cardamom bushes (Table S1, *Supplementary material*, <http://dx.doi.org/10.1659/MRD-JOURNAL-D-14-00122.S1>).

The average crop loss from diseases and pests ranged from US\$ 200 to 800 across the study sites, with especially heavy losses at Lingee-Sokpay. Although in Hee-Pechreak, Hee-Martam, and Lingee-Sokpay, the contribution of cardamom was high, crop losses by diseases and pests were also comparatively higher in these sites. The per capita

FIGURE 4 N. B. Tamling, a progressive farmer on his 10-year-old alder-cardamom farm in Hee Gaon, West Sikkim. (Photo by G. Sharma)



landholding under cardamom of the respondent households was highest (2.83 ha) at Lingee-Sokpay, followed by Hee-Martam (1.82 ha) and Hee-Pechreak (1.28 ha). The farmers here have established cardamom farms in new productive areas and are thus earning more than farmers on other sites.

Sustainability challenges and adaptive measures

Of the respondents surveyed, 91% (mostly from mid- and lower elevations) said that the weather at the onset of the cardamom flowering season was becoming drier. Around 95% of respondents said that during peak flowering season (May through July), erratic rainfall caused flower fall and decay, resulting in a loss of fruiting intensity from September to November. Almost all respondents observed that the climatic conditions are changing and that rising temperatures are causing the cardamom harvest to begin around 10–15 days earlier; around 80% said that flowering was occurring 5–10 days earlier.

The majority of cardamom farmers have developed adaptive measures, applying traditional knowledge to cope with the impacts of climate change to revive cardamom (Figure 4). The major adaptive measures are the development and introduction of improved or disease-tolerant cultivars; replanting on new farmland; bringing cardamom into home gardens where it replaces food crops; using manure to maintain soil fertility; irrigating during dry seasons; and managing diseases and pests by uprooting, drying, and burning infected plants.

With the consistent decline of large-cardamom production as the main source of income for households, the farmers have converted cardamom farms to production of food crops or fodder crops such as broom grass. In areas where cardamom yield has declined, the younger people have started looking for jobs in cities and progressive farmers at Hee-Pechreak and Hee-Martam have initiated development of *Seremna* nurseries.

Discussion

The agricultural economy in the Sikkim Himalayas is largely based on high-value cash crops, of which large cardamom is the most important. Rural farming families have, by and large, depended on the income generated from large cardamom to pay for food, housing, education, health, social activities, and farm management; the loss of cardamom production has therefore had a direct impact on local livelihoods (Sharma and Sharma 1997; Hunsdorfer 2013; Singh and Pothula 2013). Cardamom was the second largest contributor to household income after services and remittances (Table 2). Sharma and Sharma (1997) reported that the contribution of large cardamom to household income was 45% for small households and 54% for larger households. However, this contribution declined from 50% in 1997 (Sharma and Sharma 1997) to 38% in 2000 (Sharma et al 2000), while this study estimated that it had dropped to 29%. Sharma et al (2000) reported that during the 1990s the gross

income of households in large-cardamom-dominated systems was almost double that of households in traditional mixed-forest systems. Awasthe et al (2011) also reported that household income in cardamom-dominated systems was almost double that of income from mixed-forest-based traditional farming systems in Sikkim. Of the 111,830 households in Sikkim, 16,037 (14.34%) grow large cardamom as well as traditional crops (DESME 2010). Around 95% of the households in the study area have cardamom plantations. Around 40–70% of the farmland is under large cardamom; the remaining area is under traditional crops.

Climate change is becoming a well-known phenomenon in the Himalayas and is causing unpredictable and erratic rainfall, warmer weather, early flowering, less snow in the mountains and rapid melting of snow, early onset of summer and monsoon, and the drying up of water sources (Partap and Partap 2009; Chaudhary and Bawa 2011; Chaudhary et al 2011; Bawa and Ingty 2012; Sharma and Rai 2012), which is also impacting severely on cardamom-based farming systems. Climate change affects agriculture, biodiversity, and water availability and quality, among other things (Chaudhary et al 2011; Chettri et al 2012; Sharma and Rai 2012). In the Kanchenjunga landscape, to which the current study sites also belong, an annual increase in temperature at the rate of 0.01 to 0.015°C per year has been reported (Chettri et al 2012).

Study participants, both key informants and cardamom growers, perceived an increasing impact of climate change on agriculture in the form of erratic or untimely rainfall, reduction of the temporal distribution of rainfall, long dry spells from winter through autumn, rising temperature, frost and hailstorms, air pollution, a shift in seasons, extreme cold and heat, and drying springs and streams. The respondents felt strongly that research and development institutions such as the Sikkim Government Food Security and Agriculture Development Department/Horticulture and Cash Crops Development Department, and the Spices Board Gangtok, Sikkim, need to develop a strategic plan to address these challenges to revive cardamom farming.

This study has revealed the significance of local knowledge for management of large cardamom. Of the 30 factors that were identified and discussed, more than 55% of the key informants argued that all of them were responsible for the decline of large-cardamom plantation area and productivity. More than 60% cardamom growers argued that rapid drying up of springs, spread of diseases, decreased number of pollinators (due to climate change impacts), long dry spells lasting until the flowering season, and lack of training in selection of disease-free planting material, lack of growth management of cardamom for increased productivity, lack of technical knowhow for disease management, and lack of irrigation facilities were reasons for crop decline.

The difference in responses revealed that recognition of local knowledge is extremely important while developing adaptation and management plans for reviving large cardamom in the region. Farmers in the study sites have introduced new cash crops such as broom grass and ginger and nitrogen-fixing *Alnus nepalensis* trees to help maintain soil fertility. They have also planted horticultural trees in the stands where cardamom crops have completely vanished. These interventions have helped reduce soil loss by more than 22% (Rai and Sharma 1998).

The revival strategies applied through innovative knowledge systems at Hee-Pechreak and Hee-Martam led to an increase in both yield and plantation area of large cardamom: farmers have now brought cardamom from forested farmlands where they were growing it earlier to the open cultivated farmlands where they were otherwise growing cereal crops, vegetables, and pulses. They eventually applied irrigation, timely manuring, disease control measures, and appropriate shade conditions. The sharp decline in the productivity of large cardamom in several areas of Sikkim was mainly due to weak management and a change in household livelihood options followed by migration for off-farm employment (Partap et al 2014). The innovative, adaptive, climate-smart management practices can be replicated in other cardamom-growing areas.

This study identified 6 diseases, 4 insect pests, and 6 mammalian pests that are damaging cardamom crops. Saju, Deka, et al (2011) and Saju, Mech, et al (2011) have also reported the incidence of diseases and some biocontrol measures to eradicate infestations. The emergence of new diseases and pests in cardamom crops has been increasing for the last 15 years. Mammalian pests including palm civets, black bears, wild boars, Assamese macaque, and deer were reported to be damaging cardamom and other crops. Thus, human-wildlife conflict has become a serious issue in the cardamom-growing areas of Sikkim. The incidence of disease was higher at lower elevations, while pest infestations were higher at higher elevations in our study sites. The management of plantations, including shade conditions, moisture (under-canopy and soil), and altered climatic patterns have significantly altered the crop cycle. Thus, the system is now demanding more labor, increased investment in irrigation, high-quality planting materials, manure, and periodic replantation in new locations. Indeed, the impact of age on a cardamom plantation is important for optimum yield: when the stands mature the yield also deteriorates (Sharma et al 2002a, 2002b). Cardamom farmers can design periodic replantation by establishing more than one plantation stand in subsequent years, so that when the first stand becomes old, they can still continue with the other stands and earn from them while they can fallow and re-develop the first stand in a rotation system.

Climate change-induced changes in local weather are reported to increase the incidence of diseases and pests in various crops in different areas. In 1998–1999, a dry spell of about 7 months had a visible adverse effect on the large cardamom, ginger, and orange crops in Sikkim (SHDR 2001). Sharma and Rai (2012) emphasized that traditional ecological knowledge, agrobiodiversity, multiple land uses, and diversification of livelihoods allow local communities to cope with changes and will each play an important role in adaptation to climate change. Innovative approaches involving traditional knowledge or *in vitro* approaches to developing disease-free planting material for improvement of large cardamom can enhance the livelihoods of cardamom growers in the region (Pradhan et al 2014). The low performance of large-cardamom production resulted in frustration for farmers in several areas of Sikkim, and as a result, young farmers are either migrating or shifting into alternative livelihoods. Thus, a significant amount of household income is shifting away from cardamom. Nevertheless, large-cardamom farming continues to be the second largest contributor of farm income as farmers continue to drive efforts to revive and maintain their cardamom farms.

Conclusion

Cardamom-based farming in the Sikkim Himalayas is undergoing a rapid transformation owing to environmental/climatic, biological, socioeconomic, and governance/institutional drivers of change. There is a need to reduce climate change impacts by establishing

adaptation and mitigation strategies, taking into consideration local and indigenous knowledge. Some future objectives could be to develop disease-free, high-quality planting materials and establish certified nurseries, increase the spread of best management practices, improve disease and pest control, facilitate a more efficient farmer innovation process through communication, provide irrigation facilities, enhance conservation of effective pollinator species, improve product quality through improved post-harvest technology, and increase market channel efficiency, which are some of the immediate interventions that are required by the farmers.

This study has clearly established the fact that the local situations, issues, and challenges of cardamom farming are better understood by the growers than the institutions. Some contradictory responses of key informants and the cardamom growers revealed that recognition of traditional knowledge and participatory and focused approaches are critical for reviving cardamom farming in the region. The biggest threat to cardamom is the continuation of one-crop-based alder-cardamom agroforestry in India, Nepal, and Bhutan. This system now requires inclusion of mixed-species cardamom with diversification of other crops including medicinal and aromatic plants. Although cardamom farming is considered a one-crop-based but productive farming method in the region, its long-term environmental and ecological implications in the wake of climate change should be a high priority in investment for research and development.

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Supplemental material

TABLE S1 Infestations and control measures in large-cardamom plantations.

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