Geoenvironmental Disasters

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Direct impacts of landslides on socio-economic systems: a case study from Aranayake, Sri Lanka

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Abstract

Background: Landslides area controversial issue worldwide and cause a wide range of impacts on the socio-economic systems of the affected community. However, empirical studies of affected environments remain inadequate for prediction and decision making. This study aims to estimate the direct impact of a massive landslide that occurred around areas with Kandyan home gardens (KHGs)in Aranayake, Sri Lanka.

Results: Primary data were gathered by structured questionnaire from residents of the directly affected regions; the questionnaire data were combined with spatial data to acquire detailed information about the livelihoods and hazards at the household level. Satellite images were used to find affected land use and households prior to the landslide. Further, secondary data were obtained to assess the recovery cost. A multiple regression model was established to estimate the economic value of the home gardens. Field surveys and satellite images revealed that land-use practices during the past decades have caused environmental imbalance and have led to slope instability.

Conclusions: The results reveal that 52% of household income is generated by the KHG and that the income level highly depends on the extent of the land ($R^2 = 0.85$, $p < 0.05$). The extent of destroyed land that was obtained from the satellite images and the age of the KHG were used to develop a multiple regression model to estimate the economic loss of the KHG. It was found that the landslide affected region had been generating approximately US$ 160,000 annually from their home gardens toward the GDP of the country. This study found that almost all houses in the area were at risk of further sliding, and all of them were partially or entirely affected by the landslide. Among the affected households, 60% (40 houses) had completelycollapsed, whereas 40% (27 houses) were partially damaged. Because of these circumstances, the government must provide US $ 40,369 to recover the fully and partially damaged households. Finally, a lack of awareness and unplanned garden cultivation were the main contributing factors that increased the severity of the damage.

Keywords: Socio-economy, Landslide, Direct loss from the landslide, Spatial data

Background

Natural disasters are complex detrimental events that occur entirely beyond the control of humans (Alimohammadlou et al., 2013). Natural disasters can be classified based on the speed of onset; some disasters occur within seconds (landslides), minutes (tornadoes) or hours (flash floods and tsunamis) and others may take months or years to manifest themselves (droughts). Furthermore, rapid onset disasters such as landslide shave a massive impact on human life and property.

Landslides occur over a wide range of velocities and are recognized as the third most crucial natural disaster worldwide (Zillman, 1999). Landslides are usually triggered without warning, giving people less time to evacuate. Therefore, the direct impact of landslides on the socio-economic system is crucial (Christopher, 2016). Landslides are responsible for significant loss of life and injury to people and their livestock as well as damage to infrastructure, agricultural lands and housing (Schuster and Fleming, 1986; JRC, 2003; Blöchl and Braun, 2005; Guzzetti et al., 2012).Economic losses from landslides have

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been increasing over recent decades (Petley et al., 2005; Guha-sapir et al., 2011; Guzzetti, 2012), mainly due to increasing development and investment in landslide-prone areas (Bandara et al., 2013; Petley et al., 2005).

There are few studies that have attempted to quantify the impact of landslides on socio-economic systems (Mertens et al., 2017). In Sri Lanka, the socio-economic impacts from landslides have not been studied adequately. Landslides in Sri Lanka were considered a minor disaster up until the late twentieth century (Rathnaweera and Nawagamuwa, 2013). For instance, the annual average number of landslides was less than 50 until the year 2002. However, the frequency of landslide occurrence rapidly increased after 2003. Studies undertaken by the National Building Research Organization of Sri Lanka (NBRO) revealed that the number of landslides increased due to increasing human intervention such as unplanned cultivation, non-engineered construction, and deforestation.

In general, most of the socio-economic impact assessments on landslides are limited due to a lack of data (Deheragoda, 2008). Lossesfrom landslides can be estimated through the integration of field investigation, socio-economic surveys, and remote sensing. Moreover, recent studies have revealed the complexity involved in the quantification of the direct impact that landslides have on socio-economic systems (Mertens et al., 2016).

Agroforestry makes a significant contribution tothesocio-economic system of rural communities in Sri Lanka. In general, agro-forests are located on slopes, and most are vulnerable to landslides. Because of the financial benefits of agro-forestry and home gardens, the rural community is engaged in many agricultural activities, which means the land is at higher risk.

This study differs from other recent studies on the impact of landslides in many ways. First, it attempts to investigate an overview of landslides. Second, it focuses on the use of integrated remote sensing to quantify socio-economic losses in agro-forest system named Kandyan Home Garden (KHG) system to estimate the direct impact of a massive landslide on household income and property damage as a case study.

Study area

Physical setting

A tragic landslide resulted in a catastrophic situation, burying parts of the two rural villages of Elangapitiya and Pallebage. Those villages belong to the Aranayake divisional secretariat in Kegalle, Sri Lanka (Fig. 1). Aranayake is a mountainous region in the wet zone of the country. The area receives heavy rains during the rainy periods (May–September, southwest monsoon; October–November, inter-monsoon) and bright sunshine during the dry season (March–December). The average annual rainfall is from 2500 mm to 3000 mm (Jayawardana et al., 2014). The most rainfall is usually received during the monsoons. However, average rainfall amountvaries during the cyclone season.

General description of the Aranayake landslide

During the recent past, there has been no record of major landslides in the region. Therefore, people tend to use the slopes for unplanned cultivation with poor surface water management and unplanned construction. Consequently, people have less awareness of the possibility of disaster. However, evidence of paleo-landslides can be observed throughout the region. Paleo-landslides seem to have been active approximately 500–1000 years ago (Jayasinghe, 2016); hence, people living in Aranayake have few experiences of a landslide in their lifetime. In fact, observing old landslides is a good indication that the area has unstable geology and that more landslides are likely in the future. The Aranayake region experienced 435 mm of cumulative rainfall from 14-May-2016 to 17-May-2016 (~ 72 h). The exceptionally high rainfall was mainly due to the development of a low-pressure zone around Sri Lanka caused by a tropical cyclone in the Indian Ocean. This sustained torrential rainfall triggered a landslide on 17-May-2016 at approximately 16.30–17. 00 h. Thelandslide buried houses and property and resulted in massive casualties. According to field observation, this landslide was a debris flow landslide having a very complex translational model.

Socio-economic background of the area

The population of Aranayake is approximately 68,464 with 1:1 male to female ratio. Overall, 47% of the residents are permanently or temporarily employed. The high rate of dependency reaches 53% of the total population. More than 50% of the population is included in the labor force, and most of them are engaged in home garden and plantation agriculture. Although recorded incomes are low, people have alternative income sources and food security from their home gardens.

The traditional home gardens and agroforestry

Aranayake traditional home gardens and the agroforestry system clearly reflect the typical KHG system in the wet zone of the country. Home gardens in the Aranayake region have a functional relationship with the occupants related to economic, biophysical and social aspects. The Aranayake KHG consists of a mixture of annual and perennial crops, such as tea, rubber, paddies, cardamom, black paper, jackfruit, coconut, and cocoa. The crops are not grown according to any specific pattern and appear to be in a random, intimately mixed pattern. According to the typical pattern of KHGs, tea land is available on steeps slopes, rubber exists in moderate terrain and flat terrain is for paddies. In addition, minor crops can be

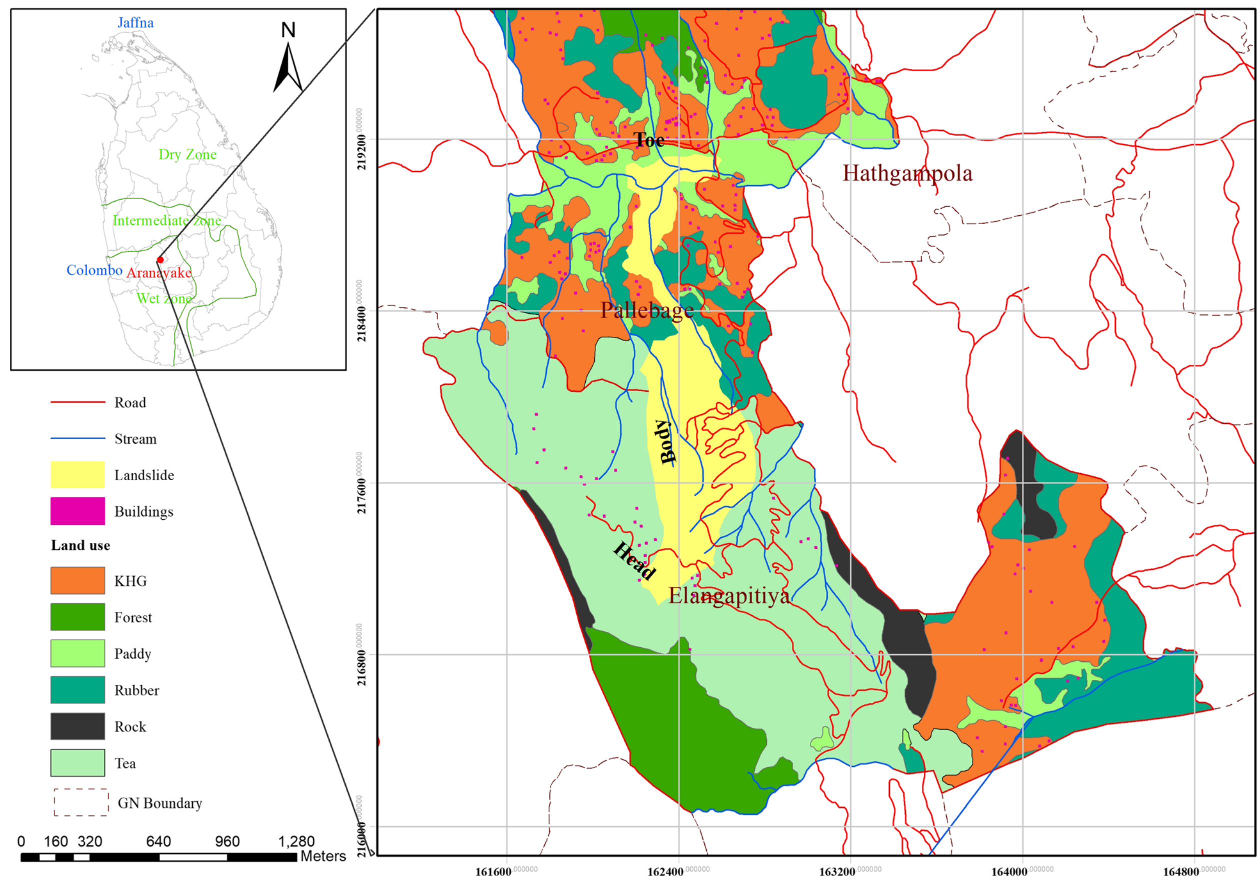

Fig. 1 Figure showing land-use of Landslide affected GN divisions; Debathgama, Pallebage, and Elangapitiya. Land use based on 1:50000 maps

seen near households. The most fundamental social benefit of KHGs is their direct contribution to a secure household food supply. The livelihood benefits of KHGs, however, are well beyond the food supply. In general, selling excess KHG production significantly improves the financial status of the community. The KHG system was significantly damaged by the Aranayake landslide reducing the income and food security of the region.

Method

Field investigation

Several exploratory field investigations were done after the landslide to grasp the overall view. Calibrated hand-held GPS was used to collect all field information. To analyze the related socio-economic conditions during the field visits, detailed studies were done on human settlement and topography.

Sampling and primary data collection

Primary data were gathered by structured questionnaire from two directly affected Grama Niladhari (GN) divisions (Fig. 1). Before data collection, a pilot survey was conducted on 30 randomly selected houses, and the questionnaire was revised according to the responses. The survey mainly covered various income sources, social capital, household demography, household type, living condition, land-use type, KHG production and landslide experience.

It was decided thatdata collection needed to be maintained at a high precision with a 95% confidence level according to the Department of Senses and Statistics of Sri Lanka standards. Sampling was done based on a proportionate stratified random sampling method from both villages (Kumar, 2007). Additionally, the following formula was used to determine the sample size (Eq. (1); Mathers et al., 2007).

$$n = \left(Z_{\alpha/2} \times \sigma/E\right)^2 \tag{1}$$

where n = *sample size,* $Z\alpha/2$ = *confidence level,* σ = *standard deviation, and* E = *error.*

According to the equation, the estimated sample size was 120under 90% accuracy levels. In this study, 127households were selected as the primary data source (592 individuals).

Secondary data collection and analysis

Secondary information and maps were predominantly used to evaluate the socio-economic status before the landside. Socio-economic data were obtained from the recently updated database in the Aranayake Divisional Secretariat. The 1:10,000 land-use data were obtained from the Land-use and Policy Planning Department (LUPPD) of Sri Lanka. The collected information and maps were used to evaluate socio-economic conditions.

The present study integrates the socio-economic and GIS data simultaneously for the landslide impact assessment. Socio-economic data were analyzed by the descriptivestatistical method, chi-squired test,and correlation analysisusingSPSS 19 software. Conversely, the spatial data processing and analyses have been incorporated using ArcGIS 10.2.

Landslide inventory and affected area mapping

Landslide boundary demarcation and mapping are essential to study the extent of damage (Guzzetti, 2006). During the past decades, use of satellite information for landslide investigation has increased significantly (Guzzetti et al., 2012). For instance, landslide damage in forest terrain has been identified by high-resolution Google-Earth images with the help of many other attributes (Guzzetti et al., 2012, Qiong et al., 2013).

Cloud-free Google-Earth images of the Aranayake landslide area were acquired. According to the images, the landslide had a clear boundary; thus, boundary demarcation was able to be accurate. In addition, ground truth GPS locations were incorporated to minimize errors. The collected information was converted to polygon data using geographical information systems (GIS; Raghuvanshi et al., 2015).

In addition to boundary demarcation, the Google-Earth data have the highest accuracy in household mapping (Escamilla et al., 2014). Therefore, the affected households were mapped using Google-Earth images before the incident and superimposed on the inventory map. In this exercise, the location of the remaining households was also mapped for cross-validation.

The affected area map was developed by overlaying the landslide inventory map with different thematic layers such as land-use type, building distribution, transportation networks and water streams in the region. Then, the affected area map was used to find the area covered by different land-use categories. In addition, real damage values for different land-use types were estimated using the affected area map incorporated with a unit value for each land-use category.

Model economic value of KHG and direct loss estimation

There is no direct method to analyze the economic value of home gardens. Generally, they are estimated by prediction models. Land size and number of years of cultivation are the typicalparameters used for estimating the values (Mohan et al., 2006). Economic values also quantify the benefit provided by home gardens (Galahena et al., 2013; Langellotto, 2014). According to the literature, the following multiple regression model was used to estimate the economic value of KHG production destroyed by the landslide (Eq. (2)). The model was established using the primary data obtained from the affected villages.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 \qquad (2)$$

where y = *economic value of a home garden;* α, β_1 *and* β_2 = *regression coefficients;* x_1 = *land area in sq.m; and* x_2 = *number of years in cultivation.*

Direct loss from the landslide was determined by assessing loss on agricultural land, damage to cultivation and households. Further, all the replacement costs for landslide related damage are considered in loss estimation.

Results and discussion

The results from social surveys revealed that the affected villages of Aranayake (Elagipitia and Pallebage) are agriculturally based rural areas depending on KHGs (Fig. 1). The unexpected landslide completely destroyed a large land area and was one of the largest landslides recorded in Sri Lankan history. Fourteen families were completely buried, and 127 lives were lost in this landslide. These results have been identified as a common feature of many massive landslides (Alimohammadlou et al., 2013). The village community has a middle-income level based on the per-capita income of the country (Table 1). Descriptive statistics of collected primary data related to total monthly income, contribution of KHG for monthly income, savings and expenditure with respect to age of the KHG is summarized in the table. However, income also depends on the diversity of KHGs. It is clear that the highest land area has been cultivated during the past two decades ($n = 54$; Table 1). Therefore, it can be conclude that land use of the region has been affected significantly during that period. This land use change contributed to increase the landslide vulnerability of the region. It was found that the landslide affected region has been generating approximately US$ 160,000 annually from their home gardens and plantations (Tea, Rubber and Paddy) toward the GDP. Thus, the results revealed that both the social and economic systems were highly influenced by the landslide, especially the KHGs in the region (Fig. 1 and Table 1).

Overview of the landslide

During the field visits, it was found that a huge amount of rocks and debris was piled up at the base of the mountain, largely consisting of gneissic boulders more

Table 1 Summary of the monthly economic status of the household in Aranayaka landslide area. Data obtained from a structuredquestionnaire survey

	A	B	C	D	E
	USD	USD	USD	USD	Acre
Age of KHG, < 10 years (*n* = 5)					
Min	77	161	110	12	1.00
Max	103	194	148	15	2.00
Avg	88	171	124	13	1.43
SD	11	14	16	2	0.42
Age of KHG, 10–20 years (n = 54)					
Min	77	161	110	12	1.00
Max	129	258	213	23	2.75
Avg	99	194	154	15	1.81
SD	13	30	31	4	0.49
Age of KHG, 20–30 years (*n* = 38)					
Min	90	161	110	12	1.25
Max	142	258	213	23	3.00
Avg	107	202	154	17	2.06
SD	14	32	28	4	0.41
Age of KHG, 30–40 years (*n* = 20)					
Min	103	194	110	15	2.00
Max	142	258	213	23	3.00
Avg	122	236	160	21	2.55
SD	12	26	35	3	0.31
Age of KHG, 40–50 years (*n* = 10)					
Min	129	194	123	15	2.00
Max	142	258	213	23	3.25
Avg	132	239	172	21	2.73
SD	5	23	27	3	0.33

n No of hHouse hold
A Monthly income from KHG
B Total monthly income
C Monthly expenditure
D Avarage monthly saving
E Own land size

than 10 m in diameter. In general, most of the human settlements are spread around the affected base area.

The average width around the landslide scarp is approximately 350–350 m, the height is approximately 50–75 m, and the widestpart of the slide is approximately 600 m. The affected home gardens and a natural vegetation cover could be observed in the surrounding area and the middle of the slide; few houses not damaged. In addition, a quite rapid and muddy groundwater flow could be observedon the right-side of the landslide, which is still flowing and forming small water streams. The debris at the toe of the landslide could be split into two regions. The left side is approximately 75–125 m in width, and the right-side is approximately 350–450 m (Fig. 2). Many houses and home gardens were located in the damaged slope, which is higher than 35 degrees (Figs. 3 and 4). The entire area had been cultivated with minor export crops (cloves, cardamom, and pepper) and fruits being common in KHGs (Perera and Rajapakse, 1991). Most of the access roads were madeofconcrete or asphalt.

Major landslide contributing factors have been identified by detailed assessment. The escarpment slope of the mountain was made up of metamorphic rocks having high joint/fracture density and thin soil overburden. Weathering conditions of the exposed slide surface of the basement rock revealed weakening along the mica and feldspar-rich layers. This mica and feldspar in the hornblende and granite gneiss can weaken the surface by intensive chemical weathering (Sajinkumar et al., 2011). In addition, due to un-planned tea cultivation and KHGs on the upper region of the slope, rainwater infiltration was quite significant. Consequently, high pore-water pressure built by the heavy, prolonged rainfall generated strong destabilizing forces on the slope (Matsuura et al., 2008). The excess pore-water pressure within the soil could have caused the reduction of shear strength and the boulders that floated on the moving debris (Kang et al., 2017).

Awareness of landslide mitigation

According to an eyewitness, there was heavy rainfall a few days before the landslide. The mountain stood calm and quiet during this rain, and no one noticed any clue of a possible disaster. It is well known that heavy rain is the main reason for massive landslides on vulnerable slopes (Gariano and Guzzetti, 2016). The villagers were awakened for a possible incident but not evacuated because there was no appropriate evacuation plan. Permanent evacuation from the possible landslide area is usually avoided due to the misleading behavior of the officials during the relocation of the residences. Despite this, it is necessary to practice successful emergency evacuation to protect the community (Huang et al., 2015). The evacuation of people is often a combinedeffort of the relevant government officials; however, there are no such systems commonly practiced in Sri Lanka. Only the NBRO issues warning awareness messages to the general public during heavy rainfall. During the early hours of the day that the landslide occurred, cracks with muddy groundwater appeared inside one house, indicating a sign of the landslide. However, all the villages were not fully aware of this matter.

In contrast, the socialsurvey reveals 80% of the residents are not ready to leave their homes, mainly due to wealthy KHG and traditional beliefs. Therefore, it is necessary to build specific awareness programs for such socio-economic systems and to educate residents on natural warning signs and the severity of disasters

Fig. 2 Figure illustrates escarpment of the landslide, evidence for human intervention in escarpment and above it and difficult translational path of the debris flow

(Bhatia, 2013). Further, the community should have a proper evacuation plan and integrated emergency management mechanism (Dorasamy, 2017). Worldwide experience has proposed community-based mitigation activities for landslides (Shum and Lam, 2011). Moreover, essential mitigation activities have not been implanted in many landslide prone areas in Sri Lanka. Community-based short-term mitigation measures such as surface drainage control, application of erosion controls and dewatering of high elevated groundwater can be implemented. Those essential mitigations will be able to control the infiltration capacity available in the KHG and to stabilize the prevailing conditions (Pushpakumara et al., 2012).

Impact of landslides on rural socio-economic systems

Human settlements are randomly spread along the landslide affected slope (Figs. 3 and 4) and are widespread in rural Sri Lanka (MHCPU, 1996). Due to gentle slope conditions, the houses are mainly located in the middle and foot regions. The inventory map reveals that

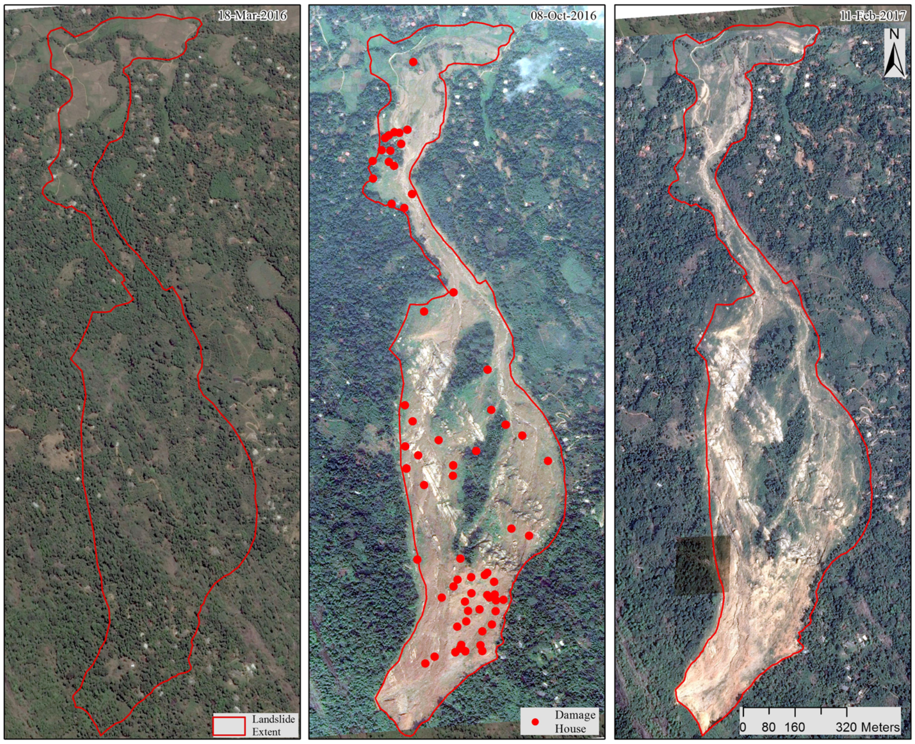

Fig. 3 Figure illustrates before the landslide occurred, just after the incident with settlements that were destroyed by the landslide and 9 months after the incident

the adverse impact at the middle and foot regions are mainly due to wideranging debris movements, which is a well-known characteristic for debris flows worldwide (Gao and Sang, 2017). The debris flow flooded over the different land uses with thicknesses of 1.5–3.5 m. However, the initial region of the landslide had relatively less impact on human settlements. Therefore, to mitigate possible damage, disaster risk preparation is necessary (Ardaya et al., 2017). More than 3 billion people live in the developing world in rural areas that comprise farming communities (Godoy, 2010). Aligning with global rural communities, most of the landslide-prone district in rural Sri Lanka, such as Aranayake, depends on KHGs. Cash crop products such as tea and rubber provide a regular source of monthly income in Aranayake. However, it was found that 98% of the tea-growing areas are owned by medium-scale producers. Therefore, tea production has an indirect contribution to the income of the local community. Conversely, minor export crops in KHGs such as pepper, cloves, and cardamom provide direct additional income (Jacob and Alles, 1987; Perera and Rajapakse, 1991). KHGs not only strengthen the household economy but also sustain food security by providing fruits, vegetables, and paddies for consumption. The present study observed multiple social benefits from traditional home gardens, such as improving family health and human capacity, empowering women, and preserving indigenous knowledge and culture. According to the remote sensing data, land uses such as tea (59%), rubber (18%), home garden (13%) and paddies (10%) covered 33.7,10.2, 7.2 and 5.8 ha, respectively, within the affected area (Table 2). Temporal analyses revealed that the natural vegetation in the affected region had been removed for plantations and home gardens during the past decades (Figs. 2 and 3). Change in land cover is considered the primary cause for debris flow slides during intense rainfall (Schneider et al., 2010). Different trees have different root patterns and penetration depth, and they can impact the stability of a slope under different soil conditions (Vergani et al., 2017). Despite short-term socio-economic gain by changing vegetation, this study reveals that slope instability is another alarming socio-economic issue. Recent past historical data show those minor export crop earnings in the Aranayake area have increased by 215% with the remarkable development of value-added products (MMECP, 2013). Descriptive statistics revealed 52% of the household income is covered by KHGs. The average monthly income of Aranayake households is US$ 205, and the mean monthly expenditure is US$ 157 (Table 1). Conversely, per capita income per month is US$ 300 with expenditure of US$ 270 (CBSL, 2016). These findings indicate that the income and expenditures of the region are lower than the national average. Despite this, low household

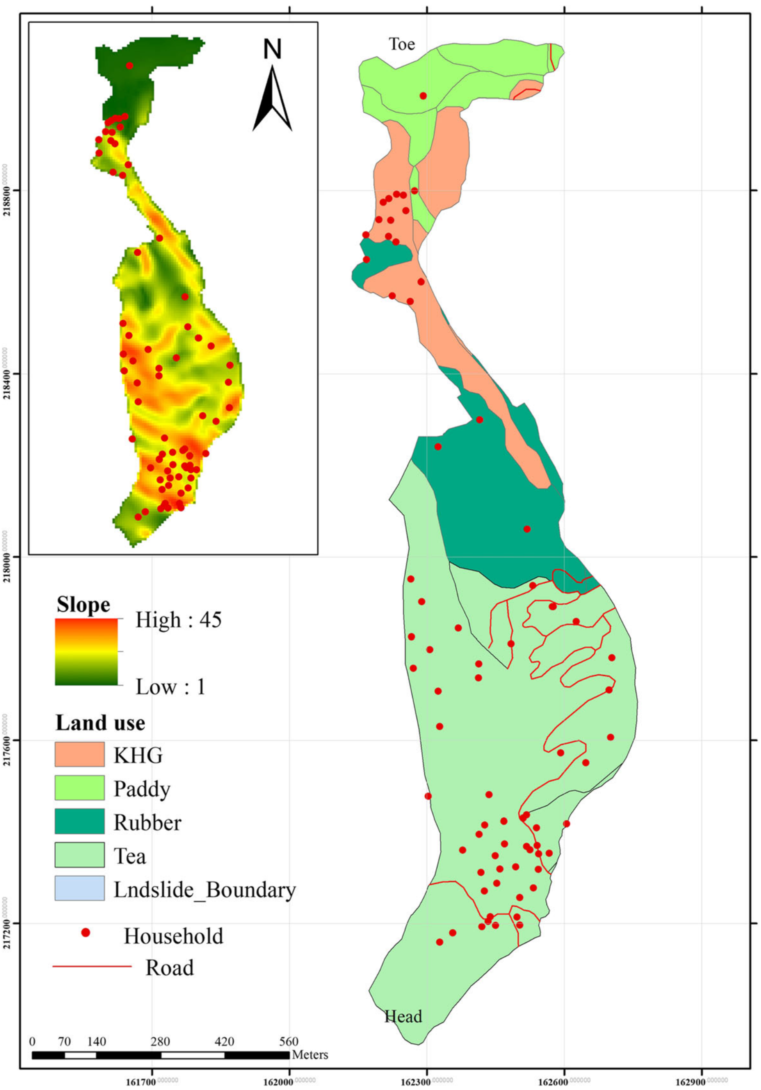

Fig. 4 Figure illustrates the outline of the landslide superimposed onto the land use of the region, distribution of different land use classes in the affected area

Table 2 Estimate the economic value of the productions from selected land-use categories available in the landslide area

Affected Land-used				
Landuse	Area		Economic value of production	Total Economic value
	hectares	acres	per Acer per year (SLR)	(SLR)
Tea	33.68	83.22	540,000.00	44,941,481
Rubber	10.21	25.23	45,000.00	1,135,324
Home Garden	7.24	17.89	42,684.00	763,634
Paddy	5.8	14.33	35,000.00	501,623
Total	56.93	140.68		47,342,061.55

expenditure is an absolute gain for the community. As a result,there is increased savings with an annual average ratio of 12%. Unfortunately, the Aranayake landslide has completely abolished such self-dependent socio-economic systems. Additionally, the communities surrounding the landslide are now abandoned, and their inhabitants are living in shelters. Most of landslide prone rural Sri Lanka that has similar socio-economic conditions is now at risk (Jacob and Alles, 1987). Thus, there should be provisions for proper socio-economic development and land-use planning to mitigate landslide disasters in the current environment.

The regression model reveals that mean monthly income has a strong positive correlation with the cultivated land area of individual home gardens ($R^2 = 0.85$, $p < 0.05$; Fig. 5). It is concluded that farmers with large

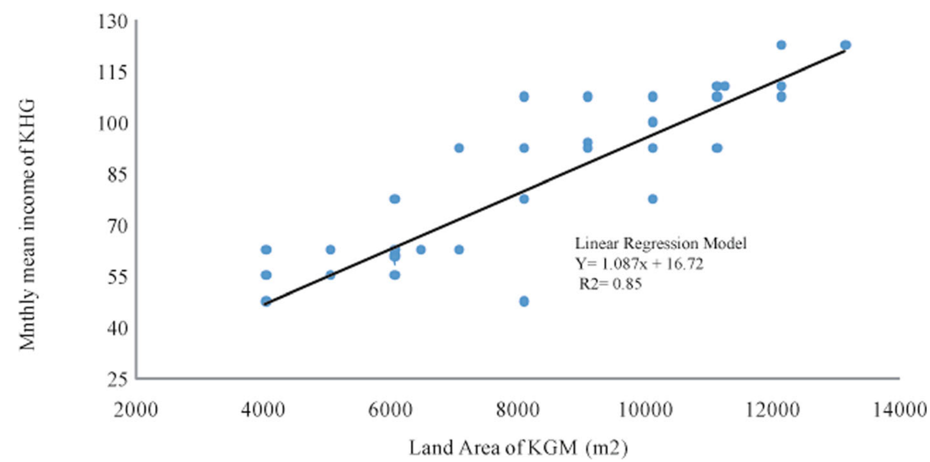

Fig. 5 Figure illustrates a linear relationship between the cultivated land area of individual home gardens size in m^2

farming area might have higher productivity per unit land and are encouraged to use the land intensively. According to damage done by the landslide to the agricultural potential of the region (Table 1 and Table 2), it is well understood that farmers who havemore significant land are willing to conserve the environment, but it was not adequately done for Aranayake. Hence, comprehensive guidelines, especially on groundwater and surface water management during heavy rainfall, will be needed to protect them from massive landslides on any slope (Masaba et al., 2017). However, this study recognizes the lack of such knowledge within the farming community.

Educational background is quite a distinct factor for disaster mitigation. The Aranayake region has educational backgrounds ranging from primary to graduate levels (Fig. 6). The results revealed that, despite the many schools available in the region, the majority of the community (< 55%) has ordinary level (junior high school) qualifications. More than 30% have completed advanced level examination (senior high school) and have qualified for government jobs. In general, previous studies indicate the positive relationship between educational level and household income (Saadv and Adam, 2016). However, household income in Aranayake is independent of the level of education ($P < 0.05$). Thisfinding may be due to additional financial gain from household farming regardless of education level. This trend may lead to less protection for the natural environment among the rural community. Despite the level of education, people in the rural community are less aware of the stability of the prevailing environment and of proper land management compared to concern for economic benefits. Human activities contribute to changing land cover types that increase slope instability and landslide risk (Proper et al., 2014).

Consequently, increased soil infiltration from poor water management in plantations and KHGs, destabilize the slope (Keith and Broadhead, 2011). Additionally, the survey reveals that 90% of local people do not have minimum knowledge of the causative factors of landslides and proper land-use plans for steep slopes.

Regression model of the economic value of KHGs

Despite the interest, economic analyses after massive landslides have not been done in Sri Lanka or for any part of the world. Hence, there is no established model to assess actual damage. This study focuses on evaluating the level of KHG damage using a regression model (Mohan et al., 2006). Primary information acquired directly from two affected villages is given in Table 1. Those data were used to model economic value using a proposed model (Eq. (3)). The result from the multiple regression model on net economic value for KHGs (Y in $) indicates that land size (X_1in m^2) and years in cultivation (X_2 in years) are statistically significant ($p < 0.05$).

$$Y = 2196 + 10.51X_1 + 20.840X_2 \quad (3)$$

Because of the uniform land use pattern in the region, this model can be used to predict the economic value of the landslide affected home gardens in any location. The total home garden affected area obtained from the remote sensing data is approximately 72,400 m^2 (Area of KHG = 7.2 Hectares, Table 2), and from the primary data, the average age of the KHG has been assumed as25years. Therefore, the estimated economic value for the entire extent of KHGs in the region is US$ 4927. This sort of estimation helps to assess the real damage to socio-economic conditions of the affected area. Additionally, it is useful to evaluate the possible evacuation of affected people and to consider their past socio-economic status for necessary subsidy estimates.

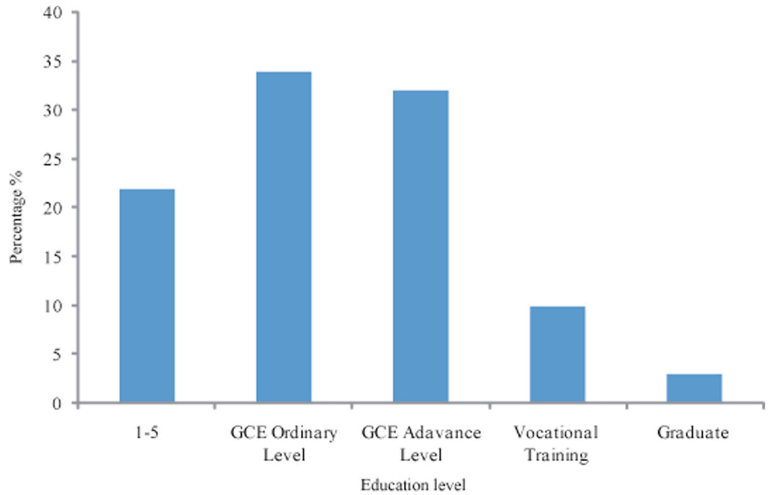

Fig. 6 Figure illustrates educational level in percentage wise in the region

Evaluation of other economic losses

Economic losses by landslide affected regions are quite significant. The highest income generated from tea was US$ 144,769 per year. From this income, only 2% is shared with the general rural community (US$ 2896). Other cultivation such as rubber, KHGs, and paddies generate US$ 7231, US$ 4864 and US$ 3195 per year, respectively, indicating the landslide affected region has been generating around US$ 160,000 for annual GDP. In addition to the disturbance, emotions and sentimentality cannot be calculated in financial terms. Nevertheless, if arbitrarily equated, this estimate would run into millions. This study revealed that landslides in rural areas could severely affecthousehold income as much as in other parts of the world (Msilimba, 2009; Haigh, 2012).

Cost estimates for the damaged houses are quite significant. This study found that almost all houses in the area are at risk for further sliding, and all of them were partially or entirely affected by the landslide. Among the affected households, 60% (40 houses) had completelycollapsed whereas 40% (27houses) were partially damaged. The department of valuation for Sri Lanka has estimated the values of the collapsed houses as SU$ 7806. Partially collapsed houses were estimated according to the level of damage. Eventually, it was found that the total cost of damaged houses is approximately US$ 40,369.

Conclusions

The results indicate that the plantations and KHGs on steep slopes are vulnerable to landslides. Landslides have significant impact on community income sources and households, and higher costs are incurred for subsequent rehabilitation and ongoing maintenance. It has been further observed that the severity of the impact on household income is highly dependent on the affected land size.

In an attempt to compensate for income loss after a landslide, household members in our sample seek self-employment or labor. The income obtained by this employment or labor does not adequately compensate for income lost due to landslides. Due to the landslide, the most economic activity was abandoned, which is not actually accounted for in the evaluation.

This study concluded that removing natural vegetation and plantations causes an imbalanced runoff-to-infiltration ratio destabilizing the slope. This result reflects that agriculture and the plantation-based socio-economic system are favorable for causing landslides, especially in the paleo-landslide environment. The results of the survey show that awareness of landslides and mitigation are the critical issues of the socio-economic system. This reduces a significant level of their income from KHGs. Based on the findings, two ultimate conclusions can be made to revive the life of affected people. They are as follows: create appropriate job opportunities apart from agriculture and introduce suitable cash crops by considering bioengineering approaches. Integrated spatial data can effectively be used for accurate loss estimates of the direct impact of landslides, and they can be used in the decision-making process of the affected socio-economic system.

Further, any changes in the frequency, intensity, and exposure to landslides require an economic assessment framework that takes into consideration household income, including the contribution of home gardens. Thisframework is important since a proper understanding of possible damage can lead to more effective emergency management and to the development of mitigation and preparedness activities designed to reduce the loss of lives andthe associated economy.

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