DAMAGE OF LANDSLIDE ON LAND USE FROM 2000 TO 2010 IN MAICHAU DISTRICT, HOABINH PROVINCE, VIETNAM

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Ảnh hưởng của lở đất đến sử dụng đất giai đoạn 2000-2010 tại huyện Mai Châu, tỉnh Hòa Bình, Việt Nam

TÓM TẮT

Lở đất sảy ra thường xuyên tại các vùng núi, nhất là vào mùa mưa tại vùng nhiệt đới như ở Việt Nam. Lở đất có thể tác động nghiêm trọng đến việc sử dụng đất và hoạt động của người dân tại các vùng núi cao. Do đó, xác định những tác hại của lở đất rất có ý nghĩa cho người sử dụng đất và các cấp chính quyền địa phương trong từng vùng xác định từ đó đề xuất các loại hình sử dụng đất thích hợp nhất. Ảnh hưởng của lở đất được phân tích chi tiết trên địa bàn huyện Mai Châu, tỉnh Hòa Bình dựa trên các phương pháp kinh tế. Kết quả cho thấy tác hại của lở đất ở đây rất lớn cho sản xuất nông nghiệp, lâm nghiệp, khu dân cư và hệ thống đường giao thông, trong đó tác hại xảy ra lớn nhất là đối với đường giao thông. Bên cạnh đó kết quả cũng chỉ ra những giai đoạn quan trọng của các loại hình sử dụng đất cần có những giải pháp để tránh hoặc giảm thiểu những tác hại khi sảy ra lở đất. Nghiên cứu cũng mang đến những cảnh báo cần thiết với người sử dụng đất ở các vùng đồi núi khác ở Việt Nam trong điều kiện biến đổi khí hậu. Tuy nhiên, việc xác định hết những tác động của lở đất không đơn giản, cần có sự nghiên cứu ở nhiều lĩnh vực khác như môi trường, con người... ở hiện tại, tương lai và trong thời kỳ dài.

Từ khóa: Lở đất, ảnh hưởng của lở đất, sử dụng đất

ABSTRACT

Landslides happen frequently in moutainous region, especially in the rainy season in tropical zone like Vietnam. The landslide can cause severe impact on land use and human activities in the highlands. Therefore, determining the damage of landslide is meaningful for local land users and officials to propose the best land use types in the specific area. Based on the economic methods, the damage of landslide was analysed specifically in Maichau District, Hoabinh Province, Vietnam. The damage was very severe to agriculture, forest, residential land and road, of which the damage ton road was the largest. Additionally, the results also indicated that the vital periods of land use types need to have solutions to avoid or mitigate the damage of landslide. The research findings provide significant warning to land users in other moutainous districts in Vietnam in the climate change era. However, identification of different aspects of landslide damage is not an easy task and this needs to do research on other fields, such as environment, human dimension,... in the present, future and long term.

Keywords: Landslide, damage of landslide, land use.

1. INTRODUCTION

Landslides are triggered by events, such as: earthquakes, rainfall and rapid snowmelt. They are influenced by multiple factors: topography, the soil and rock types, geologic fractures, etc. (Guzzetti, 2000; Sidle & Ochiai, 2006; Varnes, 1984).

According to Guzzetti et al. (1999), landslides in a specific area do not only depend on the natural condition, but also on land-uses and other human activities. Neuhäuser and Terhorst (2007) stated that the landslide susceptibility assessment has become a major

concern for authorities who are responsible for regional land use planning and environmental protection. To determine the damage of landslide, a growing research effort has been dealing with the creation of susceptibility or hazard maps which describe the actual or future threat from landslides (Lee & Dan, 2005; Pradhan et al., 2008).

Recently, landslides have been among the most hazardous natural disasters (Guzzetti et al., 1999). The damages of landslides on resident areas, infrastructures and even human casualties have been increasing worldwide (Singhrog et al., 2004 cited by Neuhäuser and Terhorst (2007)). The impacts of landslides on socio-economic development are potentially very large. Landslides can damage urban (Chau et al., 2004) or rural areas and they cause thousands of deaths and injuries. Furthermore, landslides are able to bury agricultural and forest land influencing local production.

When determining the damage of disaster, Richard (1995) stated that some of the damage costs will grow with the economy and the population, others will decline relatively, such as: agricultural losses in developing countries, and others will increase, particularly the intangibles. However, the true costs of disasters are not easy to identify and quantify because they include total direct and indirect costs and benefits. The damage of disasters can include different aspects, such as: crop losses, repairs to public infrastructure, property, and buildings. Thus, most of the losses involve physical damage to property, and disaster costs are growing largely over the world because of increasing societal vulnerability to disasters (Downton & Pielke, 2005). Based on loss model developed by Thieken et al. (2008), crop loss is calculated as a percental deduction of the perennial averaged yields. Therefore, crop losses include loss of total investment and ability to have income.

According to Sidle and Ochiai (2006: p9) and Guzzetti (2000) landslides can be triggered by many causes, such as land cover changes promoted by overpopulation, economic investment, depleted natural resources…. Additionally, landslides are related directly to climate change, especially the increase of temperature and rainfall worldwide (Coelho-Netto et al., 2007; Lee et al., 2002; Westen et al., 2006). The "Second National Strategy and Action Plan for Disaster Mitigation and Management in Vietnam from 2001 to 2020" shows that about eight thousand people were killed, 2.3 million tons of foods were destroyed, and 6 million houses collapsed and washed away by natural disasters in the decade of 1991 to 2000. The total estimated economic loss was about USD 2.8 billion, i.e. 1.8-2.3% of the national GDP or nearly USD 300 million yearly (Van et al., 2006). Ahlheim et al. (2008) assumed that affected households in northwest part of Vietnam lose about 6% of their total annual incomes as a consequence of landslide events.

According to statistical data in Maichau District, nearly 90% of the population lived in rural areas and 36.02% GDP was from agricultural sector in 2010 (GSO Hoa Binh, 2010; GSO Mai Chau, 2010). The local people in upland area, in general, and in Maichau, in particular, had some limitations of education and handcrafts. Thus, their food security and living standards depend largely on agricultural-forest activities (Cuong, 2005: p327). Damages of natural disasters on agricultural activities have been more significant because of regarding directly to local people's living. Therefore, to determine the landslide and its damage is important for not only local land users, but also local officials to propose the suitable land use types in the present and future. The research objective was to determine the damage of actual landslides from 2000 to 2010 in Maichau District. The expective results can help the local land users and officials to propose the solutions for land use strategies land use planning for the next period of development in the research area.

2. METHODS

2.1. Research area

Maichau District with its complicated terrain was conveniently selected to carry out

the study. Located in the mountainous and attractive region of the province with many beautiful landscapes and traditional customs, the district is considered as one of the beautiful districts of Hoabinh Province and northwest region of Vietnam. Moreover, the location of the district is also a crucial bridge between Hanoi and other provinces in the northwest region of Vietnam (Anonymous, 2001: p14).

2.2. Research methods

Total Landslide Damage Cost (TLDC): A number of landslide events happened in the case study district in the past 10 years from 2000 to 2010. Some of these landslides happened in areas used for agriculture, infrastructures or residential areas ("villages"). Therefore, total damage of a landslide is defined as Landslide Damage Cost (LDC). Accordingly, the landslides have caused a certain total cost (Total Landslide Damage Cost of the past 10 years: TLDC) which was determined by an equation:

$$TLDC = \sum_{i=1}^{n} LDC_i \qquad (1)$$

where I is the individual landslide i (1-n); LDC is the individual Landslide Damage Cost

To determine the Landside Damage Cost caused by actual landslides on agriculture and forest, the equation was used to analyze the data which was based on the actual investment and income of land users, as follows:

Landslide Damage Cost = Investment Lost + Potential Net Income Lost (2)

Investment Lost were all investments (total costs) in land use lost by a landslide which was calculated for each household and averaged for all households.

Potential Net Income Lost is understood as a loss of ability to have net income. If landslides did not happen, land users would have this net income that was calculated for total lifetime of crop. The potential net income was based on the actual lifetime of crop before the happening of landslide. It can be estimated as potentially yield socially desirable outcomes in agricultural activities (Fraser, 2009).

The investment period was actually long, in particularly for forest, 7 years for Acacia, and 14 years for Bamboo. Therefore, present cash flow with an interest rate for cost, revenue and net income was used to determine the landslide damage cost on forest.

The present cash flow of cost, revenue and net income were conducted by the method Future Value Analysis and Present Value Analysis (Boardman et al., 2006: p135-136); The equation was used to calculate:

$$F_v = P_v (1 + i)^t \qquad (3)$$

where: F_v: Future value; P_v: Present value; i: Interest rate; t: Time (year)

Future value: The method compares what the project will receive in the future if money invests in the project with what it will receive in the future if it invests in the best alternative. The value plus interest is called the future value, F_V (Boardman et al., 2006: p132).

Present value: A switch from future value to present value. Present Value Analysis compares the current equivalent value of investing in the project with the current equivalent value of investing in the best alternative project, given prevailing interest rates. The current equivalent value of amount that will be received in the future is called its present value, P_V (Boardman et al., 2006: p133).

Net Present Value (NPV) is calculated by equation (Boardman et al., 2006: p137):

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \qquad (4)$$

where: B: Benefit; C: Cost; t: Time (year); i: Interest rate

The damage with above indicators on agricultural land use types and forest was calculated per ha, and then the calculation will be applied in the total damaged area. Notably, the damage on forest was calculated in each year from the first to the last year of the forest

rotation with the interest rate, after that the damage was calculated with total actual affected area from 2000 to 2010 in the research area. For other land use types such as: residential land and road, the damage was calculated with each landslide event actually happening from 2000 to 2010 in Maichau District.

Household survey was conducted in the research area with 65 farm households and 64 households for forest affected by actual landslides from 2000 to 2010. The indicators are the investment and productivity, revenue, and slid area. In addition, 64 households with slid residential land were investigated, including: the value of slid house, slid area, and the price of land.

3. RESULTS AND DISCUSSIONS

3.1. Damage of actual landslides to agriculture (2000 – 2010)

To specify the damage of landslides in Maichau, 65 households affected by the actual 122 landslide events from 2000 to 2010 were investigated on investment, benefit and income. In which 17, 41 and 7 households planted rice, maize and cassava, respectively. Landslide damage cost was calculated by equation (2). The results are shown in table 1.

For agricultural crops, cost, revenue and net income were calculated per ha. From household data, the average of all households was calculated. The actual "lifetime" of agricultural crops was 3/4 total lifetime of these crops. The actual "lifetime" is defined as the time from first land preparation for seeding to the time point, when the landslide happened.

Table 1 indicates that the total costs of rice crop ha^{-1} were VND18.8 mil. higher than those of maize and cassava with VND15.4 mil. and VND11.0 mil, respectively. The revenue of rice crop, similarly, was the highest with VND25.3 mil. ha^{-1}, followed by VND19.3 mil. and VND12.5 mil. for maize and cassava, respectively. Landslide damage cost on rice crop was the largest with VND25.3 mil. ha^{-1}. The second and third were maize and cassava with VND19.3 $ml.ha^{-1}$ and VND12.5 mil. ha^{-1}, respectively.

Table 1. Damage of actual landslides ha^{-1} to agriculture (2000 – 2010)

	Rice (n=17)	Maize (n=41)	Cassava (n=7)
Seed (VND million)	2.70	2.37	0.00
Plough land (VND million)	2.97	2.46	2.38
Fertilizer (VND million)	4.43	2.96	2.46
Pesticide (VND million)	2.27	0.81	0
Paid labour (VND million)	5.31	5.95	5.32
Other costs (VND million)	1.11	0.83	0.83
Total costs(VND million)(Investment Lost)	18.79	15.38	11.0
Productivity (ton/ha)	4.60	2.98	8.36
Price (million/ton)	5.5	6.5	1.5
Revenue (VND million)	25.30	19.34	12.54
Net income (VND million)	6.51	3.97	1.54
Potential net income lost (VND million)	6.51	3.97	1.54
Landslide Damage Cost (VND million)	25.30	19.34	12.54

Source: Own investigation and calculation

3.2. Damage of actual landslides to forest (2000-2010)

To determine the Landslide Damage Cost on forest from 2000 – 2010 in Maichau, 64 forest planting households damaged by actual landslides were investigated in detail. In which 4 and 60 households planted Acacia and Bamboo, respectively. These households were affected by 64 landslides in the research area. For the affected Acacia and Bamboo plantings, two different forest rotations need to be applied in the calculation of potential net income: 7 years for Acacia and 14 year for Bamboo. The landslides can happen in any of the 7 or 14 years of the rotation. Thus, present cash flow was applied to carry out for each year with the interest rate 9% per year.

The costs and revenue were investigated in each year of forest cultivation. The costs included seedling for the first year, fertilizer, labour and others for all forest lifetime. The forest revenue gained annually. However, Acacia was harvested merely one time in the last year of the rotation and to mainly supply pulp industry. For bamboo, harvesting was carried out during the dry season, from November to following January from the 5^{th} year of the rotation when the culm nutrient and starch content are the lowest with the aim to prevent culms being attacked by borers (Ha, 2010: p95). Bamboo shoot is a by-product of bamboo, and it contributes largely to total revenue.

Notably, landslides probably happen in different periods of the forest rotation. The happening can range from 1^{st} year to 7^{th} year for Acacia and 1^{st} year to 14^{th} year for bamboo. Therefore, the happening was simulated by possibility from 1^{st} to 7^{th} year for acacia and 1^{st} to 14^{th} year for bamboo. Present cash flow of cost, revenue and income of forest was calculated by equation (3). Landslide Damage Cost on forest was calculated by the equation (2).

Obviously, potential net income is understood as an indispensable part of total damages to forest. It would be able to have an income if landslides did not happen. In fact, it was calculated in each year of the rotation. In actual investigated data, present cash flow was calculated and is shown in the table 2 and table 3.

The results, synthesized in table 2, 3, and fig 1, indicated that the landslide damage cost changed quite differently between acacia and bamboo. Indeed, for acacia, the damage raised steadily from the $year^{+1}$ to the last year of the rotation by roughly VND65.0 mil VND from around VND14 mil.

Table 2. Damage of actual landslides on Acacia ha^{-1} in Maichau District

Year landslide happened	Accumulated							
	Total costs (Investment)	Total revenue	Net income	Present cash flow (Cost)	Present cash flow (Revenue)	Present cash flow (Net income)	Potential Net Income	Landslide Damage Cost
$Year^{+1}$	9.56	0.00	-9.56	9.56	0.00	-9.56	4.32	13.88
$Year^{+2}$	12.20	0.00	-12.20	13.06	0.00	-13.06	9.42	22.47
$Year^{+3}$	13.57	0.00	-13.57	15.61	0.00	-15.61	15.40	31.00
$Year^{+4}$	14.95	0.00	-14.95	18.39	0.00	-18.39	22.37	40.76
$Year^{+5}$	16.32	0.00	-16.32	21.41	0.00	-21.41	30.49	51.90
$Year^{+6}$	17.70	0.00	-17.70	24.72	0.00	-24.72	39.88	64.59
$Year^{7}$	19.17	0.00	-19.17	28.42	0.00	-28.42	50.71	79.13

Source: Own investigation and calculation (Unit: VND million)

Table 3. Damage of actual landslides on Bamboo ha^{-1} in Maichau District

Year landslide happened	Accumulated							
	Total costs (Investment)	Total revenue	Net income	Present cash flow (Cost)	Present cash flow (Revenue)	Present cash flow (Net income)	Potential Net Income	Landslide Damage Cost
Year^{+1}	6.48	0.00	-6.48	6.48	0.00	-6.48	3.72	10.19
Year^{+2}	8.62	0.00	-8.62	9.21	0.00	-9.21	8.10	17.31
Year^{+3}	10.73	0.00	-10.73	12.14	0.00	-12.14	13.24	25.38
Year^{+4}	12.51	0.00	-12.51	15.01	0.00	-15.01	19.25	34.26
Year^{+5}	14.29	0.00	-14.29	18.15	0.00	-18.15	26.23	39.13
Year^{+6}	16.07	5.57	-10.50	22.37	6.07	-16.29	33.96	50.25
Year^{+7}	17.86	13.83	-4.03	25.28	15.62	-9.67	43.62	53.29
Year^{+8}	19.64	27.56	7.92	29.34	31.99	2.65	54.34	51.69
Year^{+9}	21.42	45.51	24.09	33.77	54.43	20.67	66.63	45.97
Year^{+10}	23.20	63.85	40.65	38.59	79.33	40.74	80.70	39.96
Year^{+11}	25.04	82.20	57.16	43.89	106.47	62.57	96.76	34.19
Year^{+12}	26.87	102.15	75.27	49.68	137.79	88.11	115.06	26.95
Year^{+13}	28.78	121.29	92.52	56.06	171.06	115.01	135.86	20.85
Year^{+14}	30.74	140.44	109.70	63.07	207.33	144.26	159.48	15.22

Source: Own investigation and calculation (Unit: VND million)

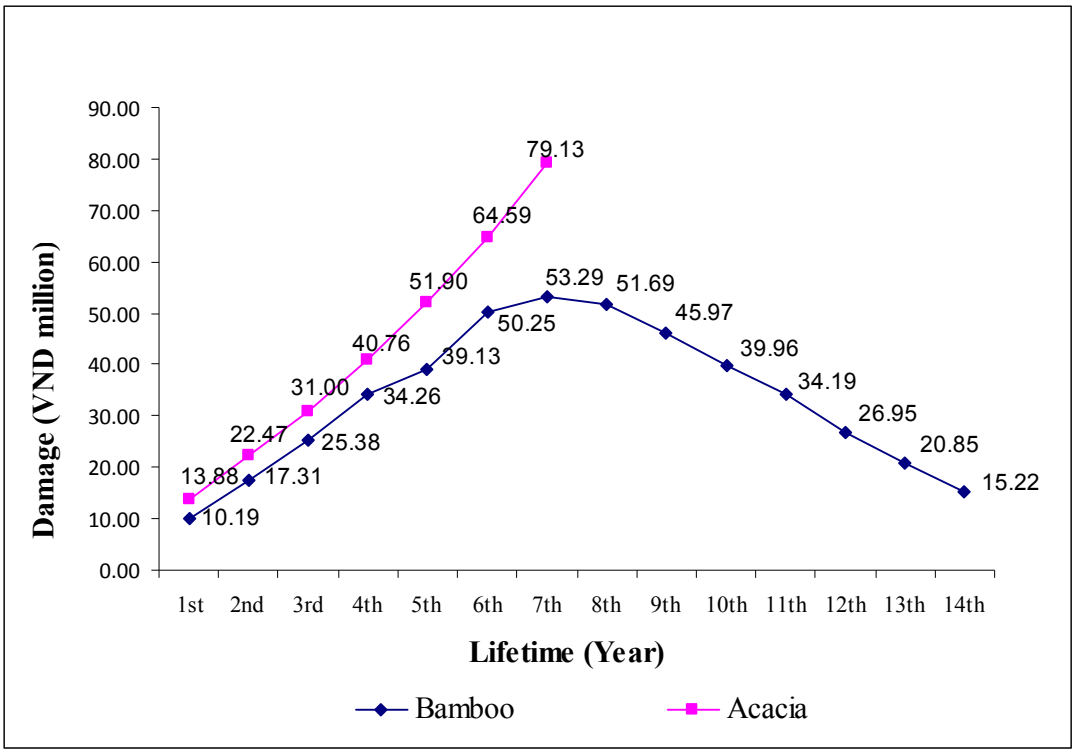

Fig. 1 Landslide damage cost ha^{-1} on forest in Maichau District

Mil. to VND79 mil., respectively. On the other hand, the damage to bamboo was glanced as a concave down parabola with the highest peak of VND53.3 mil. at the year^{+7} of the lifetime. The downward went gradually into the year^{+1} and year^{+14} with around VND10.0 mil. and VND15.0 mil., respectively. Thus, the economic income in the year^{+6}, year^{+7}, year^{+8} of bamboo rotation and year^{+7} of acacia rotation was the largest. As the revenue was the largest and the investment was the lowest in this period

The results assume that the year^{+7} of acacia rotation and the year^{+6}, year^{+7}, year^{+8} of bamboo rotation were important periods of forest lifetime. If landslides happen in this time, total losses will be the largest. The hypotheses suggest that if proper types of land use are proposed to prevent landslides in this time, such damages could be lessened to as low as possible. These results also have important implications for land users and planners in land use and land use policies in the present and future development.

3.3. Damage of actual landslides to residential area and peoples' lives (2000-2010)

Land where the users are allowed to have one of the following rights: to exchange, transfer, lease, sub-lease, inherit, donate, mortgage land use rights, provide guarantee or make capital contribution with land use rights (article 61) (Anonymous, 2003). In addition, population growth is high (around >1%), indeed it is 1.05% in 2010 (GSO, 2010). According to demographic investigation, the average growth from 1999 to 2009 was 1.2% in comparison with 1.7% in the previous period (Anonymous, 2010). Therefore, the growth has caused a huge pressure to expand the residential area.

Table 4. Damage of actual landslides on residential area (2000-2010)

Commune	ID of Landslide	No of destroyed household	Damage on house (VND million)	Affected area (m^2)	Price of residential land (1000 VND/m^2)	Damage on residential land (VND million)	Landslide Damage Cost (VND million)
1	2	4	5	6	7	8=6x7	9=5+8
Pa Co	2	0		400	50	20.00	20.00
Pa Co	3	0		308	35	10.78	10.78
Hang Kia	4	1	100.00	300	30	9.00	109.00
Tan Son	7	0		300	55	16.50	16.50
Bao La	20	1	100.00	2,100	50	105.00	205.00
Bao La	23	1	80.00	400	45	18.00	98.00
Tan Mai	56	13	245.00	1,000	35	35.00	280.00
Phuc San	58	11	269.00	1,400	60	84.00	353.00
Dong Bang	61	3	300.00	700	55	38.50	338.50
Ba Khan	64	0		400	30	12.00	12.00
Tong Dau	66	1	30.00	1,200	60	72.00	102.00
Dong Bang	67	1	130.00	400	60	24.00	154.00
Dong Bang	68	3	370.00	320	60	19.20	389.20
Dong Bang	69	2	100.00	1,500	60	90.00	190.00
Tong Dau	76	5	125.00	1,200	110	132.00	257.00
Noong luong	101	0		400	30	12.00	12.00
Noong luong	104	0		800	30	24.00	24.00
Van Mai	116	12	580.00	1,200	70	84.00	664.00
Pu Bin	119	0		800	35	28.00	28.00
Total	19	54	2,429.00	15,128		833.98	3,262.98

Source: Own investigation and calculation

In the research area, the calculation of landslide damage cost on residential area included damage on residential land and damage on houses. Residential land has the highest value in comparison with agricultural and forest land. It is considered as the most valuable asset for farmers. Therefore, the value of land should be included in the landslide damage cost. The price of residential land was stipulated by the Maichau District' People Committee Chairman in Decision No 34/2011/QD-UBND. The price ranged from VND30,000 to VND600,000 for rural area and from VND 45,000 to VND2,200,000for urban area.

Totally, 19 landslides that affected residential area were investigated in 11 communes of the district. In fact, 63 households were affected by landslides from 2000-2010. In which, 54 houses of households were destroyed by landslides. The household interview questions included: How much residential area was affected by landslides? Was the house destroyed by landslides? How much money was lost by landslides? The results are shown in table 4.

The results indicated that from 2000-2010, residential area was affected by 19 landslides, of which the damage of landslides to residential land was nearly VND834 mil.. And the damage on local people's houses was estimated as very high with VND2.429 mil. belonging to 54 households severely devastated by 12 landslides in 7 communes in the research district. Total landslide damage cost on residential area including damage on residential land and damage on houses was roughly VND3.263 mil. that contributed largely to total landslide damage cost from 2000 to 2010 in Maichau District.

According to the investigation, 6 deaths were caused by landslides from 2000 to 2010 in the district. All killed individuals were from 30 to 35 years old. They could have worked in the next 30 years, if landslides had not occurred. Based on the economic point of view, this "damage" can be approximated in monetary terms using per capita GDP figures. The data in table 5 showed that total damage of landslides on deaths was VND541.14 mil.

3.4. Damage of actual landslides to road system (2000-2010)

The investigation was carried out at the Department of Transportation and at communes. The statistical data on the damage of actual landslides to the road system was collected directly. Specifically, the length of the road, the volume of removed land and the cost of reconstruction of the road were surveyed in the Department of Transportation. Finally, this data were confirmed in the communes when the field trip was conducted.

The results showed that a total of 1,275 m of the road system was impacted by 10 landslides from 2000-2010. The landslide damage cost on roads was calculated by the cost of reconstruction these roads and the cost of removal of land triggered by landslides. The price to remove land and reconstruct the slid roads was calculated based on the Decision No 2107/2007/QD-UBND stipulated by the people committee chairman of Hoabinh Province. The cost to remove land ranged from VND82,000 to VND118,000 per m^3 depending on the rock level in land. The cost of reconstruction was roughly VND2.0 billion to VND2.5 billion per km. The table 6 showed that the total landslide damage cost on the road system was around VND5.8 billion which also accounted significantly for the total landslide damage cost in the district.

Table 5. Damage of actual landslides on death (2000 – 2010)

Number of death	GDP per capita (Million VND)	Working duration (year)	Interest rate (%)	NPV (Total loss) (Million VND)
6	8.0	30	9	541.14

Source: Own investigation and calculation

Table 6. Damage of actual landslides on road system (2000 – 2010)

Commune	ID of landslide	Length of Road (m)	Volume of removed land (m^3)	Cost of movement of land(VND million)	Cost of reconstruction (VND million)	Landslide damage cost (VND million)
Tan Son	10	150	3150	270.90	375.00	645.90
Cum Pheo	14	250	4500	531.00	625.00	1,156.00
Bao la	23	100	2800	240.80	250.00	490.80
Tan Dan	38	100	2000	164.00	250.00	414.00
Phuc San	60	200	4800	412.80	500.00	912.80
Ba Khan	65	50	900	106.20	125.00	231.20
Dong Bang	69	100	2700	232.20	250.00	482.20
Na Meo	83	150	3150	258.30	375.00	633.30
Thung Khe	97	125	2250	265.50	312.50	578.00
Van Mai	113	50	1050	123.90	125.00	248.90
Total	10	1,275	27,300	2,605.60	3,187.50	5,793.10

Source: Own investigation and calculation

According to equation (1) total landslide damage cost was nearly VND13.42 billion including damage to agriculture (VND1.15 billion), forest (VND2.68 billion), residential land (VND3.80 billion) and road (VND5.79 billion).

4. CONCLUSIONS

The impact of the landslides on the district's economy was quite large. Nearly 3% of Maichau's GDP in 2010 (VND422 billion (GSO Mai Chau, 2010)) was lost by landslides. With annual GDP per capita VND8.0 mil. (GSO Mai Chau, 2010), the landslides in the past 10 years caused the loss of income of around 1,600 inhabitants or roughly 350 households. Local people and the district's economic situation were, therefore, burdened substantially with landslide damage cost. Indeed, total landslide damage cost of 122 actual landslides from 2000 to 2010 was around VND13.42 billion and 6 deaths in the research district. Total damaged area was 114.10 ha, including: 56.28 ha agriculture, 55.48 ha forest, 1.51 ha residential land and 0,83 ha road (1.3 km). Furthermore, others damages of landslides likely affected the living conditions of local people, such as: transportation problems caused by road damages or reduced or degraded water supply.

In terms of the landslide damage analysis, the effect on the road system was very large. Own data can be used here, however, as a starting point for more detailed investigations. For example, a future LUP may suggest to plant forest trees on the high areas along to the roads and build special constructions in the high susceptibility areas to protect the road system.

At the level of detailed results, the landslide damage analysis demonstrated that the damage on rice crop was greatest, followed by maize and cassava. For forest, if landslides happen in the year^{+7} for acacia and year$^{+6,+7,+8}$ for bamboo, the damage will be the largest. This finding is meaningful for land users and authorities to propose proper solutions to protect forest trees in the vital periods of the forest rotation and the annual crops.

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