Landslides and Terraced Paddy Fields in the Western Middle Moun-tains of Nepal : A Case Study for a Perspective of Watershed Environmental Management

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Landslides and Terraced Paddy Fields in the Western Middle Mountains of Nepal: A Case Study for a Perspective of Watershed Environmental Management

Toshikazu TAMURA

Abstract There is a controversy whether paddy rice cultivation in chronic landslide zones is skillful agricultural use of hillslopes prepared by previous slides or careless use which accelerates sliding movement. In the Middle Mountains of Nepal, many paddy terraces are conditioned by, affected by, or inducing different types of landslides, some of which may develop to big and catastrophic slides. Both residents and local officers have not perceived the situation in most cases and many farmers are tenacious to paddy cultivation even if their paddy terraces suffer from landslide frequently. Environmental management of a watershed in which dominate particular geomorphic processes interrelated with human action should be planned on the basis of reliable information on landslides which incorporates the evaluation of farmers' perception and behavior as environmental impacts. Moreover the information should be transmitted to farmers in an apprehensible form as they can manage land-use by themselves.

Key words: paddy terrace, landslide, Middle Mountains of Nepal, watershed environment, environmental management.

1 Introduction

The relation between landslide and paddy terraces presents an issue of land-environmental management peculiar to hilly areas in Monsoon Asia where paddy rice is widely favored. Landslide, particularly deep-seated slide, produces relatively gentle hillslopes with thick soil and, frequently, plenty of surface or shallow subsurface water. Such a landform provides a rather convenient condition for paddy rice cultivation in a hilly area which is usually inconvenient for paddy fields, because they requires flat lots filled seasonally with shallow water. On the other hand, paddy rice cultivation in landslide zones must accelerate infiltration of water which may activate sliding

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or creeping movement.

The reciprocal relation has been indicated and discussed in the context of wise land-use and successful landslide control in many chronic landslide zones in Japan (e.g., Koide, 1955, 1973). Recent situation of paddy rice cultivation in many Japanese landslide zones is, however, that depopulation has made difficulty in maintenance of terraced paddy fields (e.g., Nakajima, 1996). The Middle Mountains of Nepal, which provide one of the major populated zones in the mountainous country, presents more drastic and serious issues of landslide and agricultural land-use. The issue on the relationship between deforestation and landslide, in particular shallow regolith slide mostly of slump type, has been comprehensively treated in Ives and Messerli (1989).

This paper describes some typical cases of relations between paddy terrace construction/cultivation and landslides which are not restricted to shallow regolith slump. The field research which was carried out in Kaski and Parbat Districts, Western Nepal, ranges from observation of land and land-use to hearing of residents' perception of land and landslide. The results will be discussed in order to develop the framework of environmental management and sustainable land-use in a watershed scale.

2 Outline of the study areas

The land of Nepal is geomorphologically divided into five zones as shown in Fig. 1. Among the zones, the Middle Mountains consist of hilly terrain of the altitude ranging

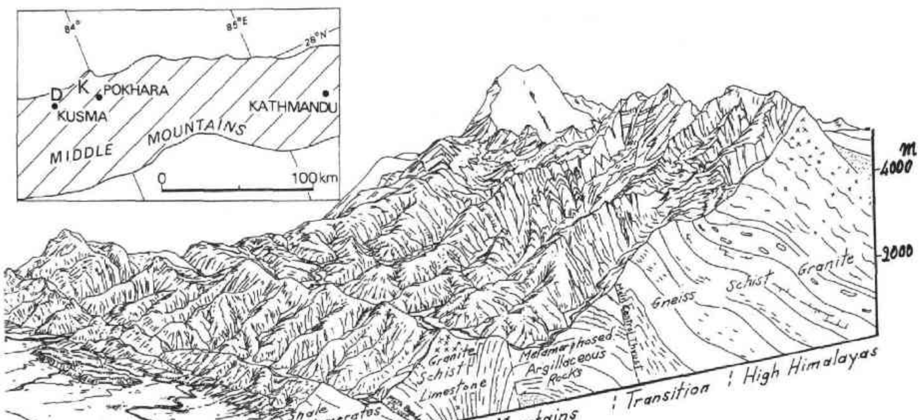

Fig. 1 The geomorhic zones of Nepal (Nelson *et al.*, 1980) and the location of study areas. K Kaskikot, D Durlung. The hatched area indicates the Middle Mountains.

from about 4,000 m to 1,000 m composed mostly of Precambrian metasediments associated with granitic intrusives. The Middle Mountains which occupy about 30% of the national land area (Kenting Earth Sci. Ltd., 1985) is estimated to have about 30%[1] of national population in the 1990s. Although the ratio has been decreasing because of the mass migration towards Terai Lowland since the suppress of malaria in the 1950s, total number of inhabitants in the Middle Mountains does not seem to be in decreasing trend[1].

Settlements and cultivated lands tend to be located on gentle dip-slopes of the mountains controlled by the structure of schist/phyllite, while steep scarpslopes are extensively occupied by forest (Photo 1). Cultivated land on the slopes inevitably takes the form of terraces which are traditionally classified into *bari* and *khet*[2].

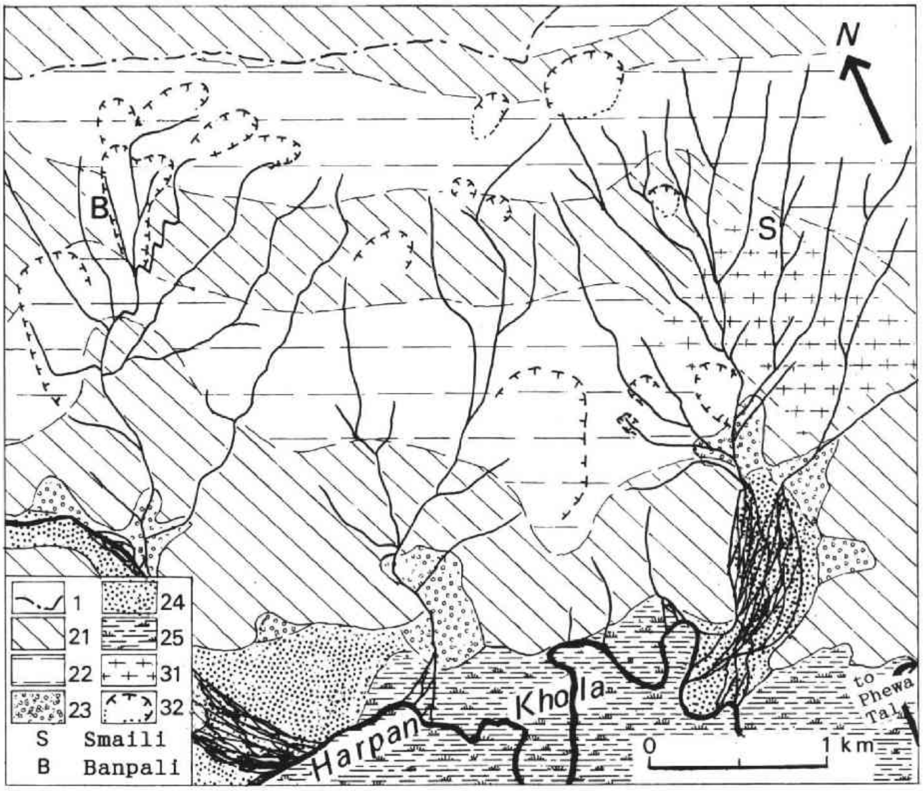

Fig. 2 A geomorphological sketch map of the left side of the Harpan Khola, Phewa Tal watershed.
1 Main divide ; 21 Steep hillside zone, 22 Gentle hillside zone, 23 Talus and Alluvial cone, 24 Alluvial fan-type floodplain, 25 Meander belt-type floodplain ; 31 The zone of terracettes susceptible to stripping off of shalow soil on impermeable bedrock, 32 Probably deep-seated landslide.

Terraced fields are in some areas affected by shallow regolith slide and induced debris flow (Photo 2). The phenomena have been frequently considered as a consequence of deforestation, as introduced in Ives and Messerli (1989). In addition, several other types of landslides take place in relation to geologic and geomorphic conditions.

Some of the study sites are located in the Phewa Tal watershed, 8 to 20 km west to northwest of Pokhara (Figs. 1 and 2). The left side divide of the watershed is formed by a west-northwest to east-southeast stretching ridge about 1,400 to 1,800 m above the sea-level. Gentle to moderate slopes around 10 to 30 degrees and steep slopes more than 35 degrees alternate on the hillsides[3] underlain by Precambrian schist/phyllite which show general trend of southward dipping. The lower end of the hillside is bordered by a floodplain less than 500 m across and about 800 m above the sea-level (Fig. 2). Many small villages accompanied by dry and wet terraced fields are scattered on gently to moderately sloping hillsides. However, some fields and settle-

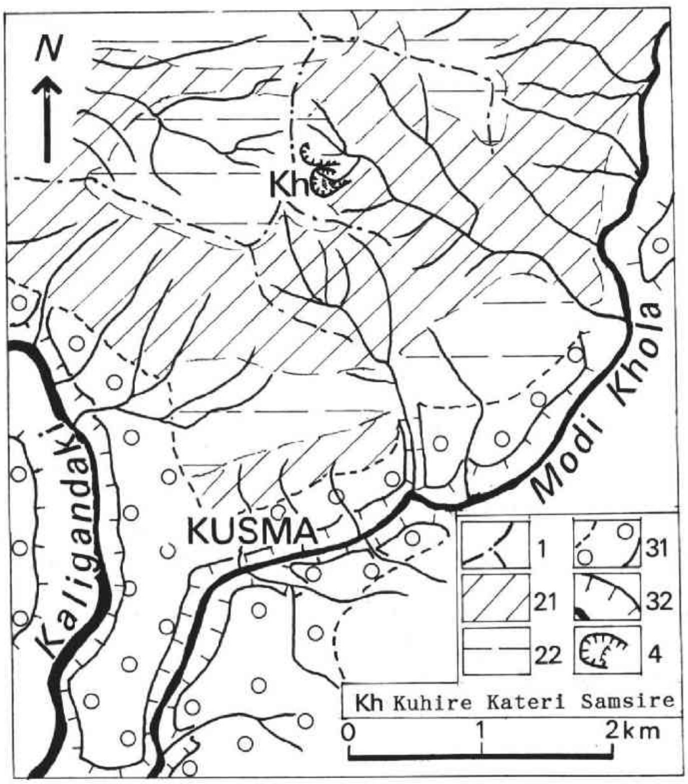

Fig. 3 A geomorphological sketch map of the left side of the lower Modi Khola, an eastern tributary of the Kaligandaki.
1 Main divide ; 21 Steep hillside zone, 22 Gentle hillside zone ; 31 Fluvial terrace and gentle slope behind, 32 Terrace scarp ; 4 Probably deep-seated land slide.

ments have advanced recently to steep slopes and floodplain of the Harpan Khola which flows into Phewa Tal. The lake, which seems to have appeared by rapid filling of the Seti Khola valley probably by glacial lake outburst floods during recent 1,000 years (Yamanaka et al., 1982 ; Yamanaka, 1982), has suffered from rapid sedimentation particularly in its westernmost part (Leminen, 1991).

The other study site is located about 35 km west of Pokhara. It rests on the northwest side of the Modi Khola which joins the Kaligandaki near Kusma (Figs. 1 and 3). The gentle crest-slope about 1,500 to 1,800 m above the sea-level is extensively occupied by settlements and dry fields. Relatively steep hillsides are partly cultivated and mostly forested while some of a little gentle slopes scattered on valley heads are used for paddy terraces. The steep hillsides composed of westward dipping phyllite/schist extend 1 to 2 km long and 600 to 700 m high. The lower end of the hillsides is bordered by narrow bottomland or a high river terrace, which are also the result of rapid valley filling due to glacial lake outburst floods during recent about 1,000 years (Yamanaka and Iwata, 1982 ; Yamanaka, 1982) of the Modi Khola (Fig. 3).

3 Very shallow soil slides/flows conditioned by paddy terracette construction — A case at Smaili

At Smaili in Kaskikot VDC[4)], Kaski District, about 10 km west-northwest of Pokhara (Fig. 2), a dipslope around 25 to 30 degrees and more than 1 km long is composed of resistant and impermeable schist. The bedrock extensively exposed and some streams flow down on it without entrenching. Very thin stony soil less than 30 cm thick on the bedrock slope is artificially accumulated to construct innumerable very small paddy terracettes one to a few meters across (Photos 3 and 4).

Although slope and soil condition for cultivation is very poor, it is rather easy to conduct water from streams flowing on impermeable rock floor to adjacent paddy terracettes (Photo 4). On the other hand, very thin soil resting on impermeable rock readily produces saturation by water in the case of heavy rain. The terracettes are thus eroded off almost every rainy season. Debris produced by the destruction of paddy terracettes flow downslope to attack dry fields which were recently constructed on alluvial cones and floodplains by immigrants from the upper hillsides to the footslopes (Photo 5).

Phewa Tal Watershed Management Office has noticed the unfavorable situation and has prohibited cultivation on hillslopes at Smaili. This regulation is partially observed and trees have been planted on some former paddy terracettes. However, cultivation is still continued on most paddy terracettes and those which were destroyed in the former heavy rain are reconstructed. Such behavior of farmers is caused by their perception that paddy terracettes are important resources for rice production, although their productivity is low, on hillslopes where suitable land for rice cultivation is scarce. The behavior should be considered from the viewpoint of not only the necessity of self supply of food but also the preference to rice.

The geologic and geomorphic condition of Smaili seems to resemble to the hillslope around Palung, upper Kulekhani watershed about 35 km southwest of Kathmandu, where big lanslides and debris flows were induced by the heavy rain in July, 1993 (Dhital et al., 1993; Water Induced Disaster Prevention Technical Center and Central Department of Geology, Tribhuvan Univ., 1994). Moreover, many signs of deep-seated rock/debris slides are observed on the hillsides in and around Smaili (Figs. 2 and 4). Both the Watershed Management Office and residents have not yet perceived the possibility of bigger mass-movements than shallow soil slides/flows which take place in association with paddy terracette construction.

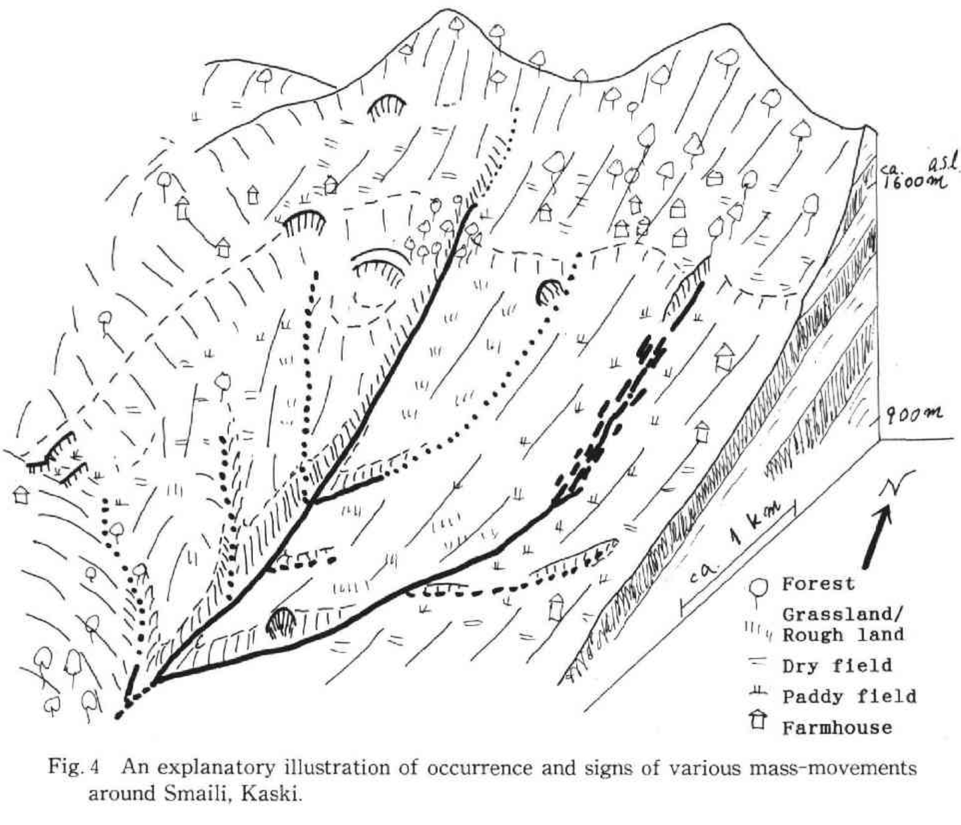

Fig. 4 An explanatory illustration of occurrence and signs of various mass-movements around Smaili, Kaski.

4 A deep-seated slide providing "fertile" paddy terraces affected partially by cracking — A case at Banpali

In a part of Banpali in the Kaskikot VDC, 13 km west-northwest of Pokhara (Fig. 2), paddy terraces are extended on the hillslope about 30 degrees (Photo 6). Conditioned by thick soil over 2 m and continuous supply of surface and shallow subsurface water, paddy rice cultivation had been steadily continued during more than 50 years on the hillslope. However, many cracks and some shallow slides have been recently appeared on the paddy terraces which had been more fertile than neighboring fields (Photo 7). In addition to this, rat activity seems to enlarge and elongate the cracks in part. Irrigation water, manure and fertilizer are lost through the cracks and the productivity has been thus lowered on the affected fields. Taking notice of the earth-surface phenomena, an owner of the affected fields has stopped cultivation and has planted trees on his damaged terraces.

Several surface features in and around the affected paddy terraces suggest that the site as a whole has been developed through continuing slide whose slip surface is seated

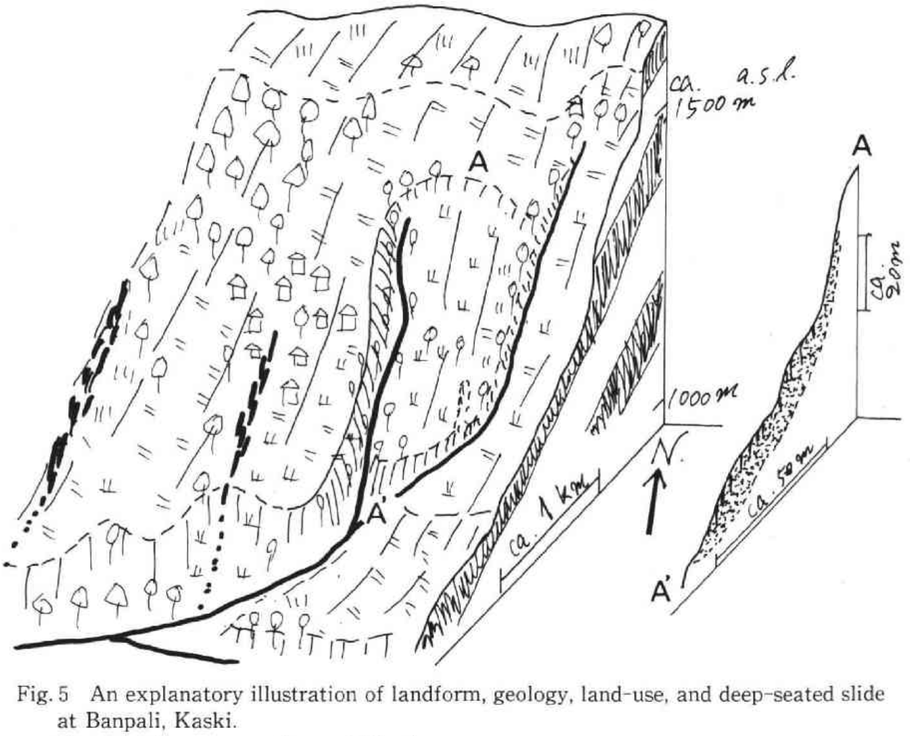

Fig. 5 An explanatory illustration of landform, geology, land-use, and deep-seated slide at Banpali, Kaski.
Keys are the same as those of Fig. 4.

on deeper position almost parallel to dip-slope, as observed frequently in crystalline schist zones in Japan (Fig. 5). A head scarp and side scarps delineate the slide zone about 300 m across and 800 m long, from surrounding non-slide zone which is occupied by terraced dry fields in contrast with the slide zone used as terraced paddies. Farmers told that the dry field area is lacking of sufficient water for paddy rice cultivation. Recent cracking and surface slides on the paddy terraces are thus recognized as a sign of activated creeping in the deep-seated slide zone. Moreover, a little gentler hillslope with thick soil and water supply is also a product of continuing deep-seated slide. In other words, the deep-seated slide at Banpali has provided relatively suitable condition for paddy terrace construction and continuing cultivation on the hillside dominated by steep slopes. At the same time, the geomorphic condition has recently hindered cultivation.

Although both farmers and local soil conservation officers are considering of countermeasures to cracking, they do not perceive the deep-seated creep as a cause of the surface phenomena.

5 Check dam construction against shallow slides as surface phenomena occurred in a continuing deep-seated slide zone — A case at Kuhire Kateri Samsire

Terraced paddy fields are distributed on the east-faced slope around 25 degrees bordering the gentle crest slope on which the settlement of Kuhire Kateri Samsire, Durlung VDC, Parbat District, is located (Fig. 3 and Photo 8). Water springs observed at various parts of the paddy terrace area are utilized for irrigation. Gray soft clayey soil with mottles also seems to provide suitable condition for paddy rice cultivation. However, considerable parts of the paddy terraces have been abandoned because of extending cracks (Photo 9). Residents have noticed the cracking since the late 1970s. Moreover, active gullying and associated surface slides on the paddy-terraced slope have produced much debris to be transported downstream (Fig. 6 and Photo 10).

Although a head scarp and side scarps are not so clear, the terraced slope as a whole, several tens of hectare in area, is considered a deep-seated slide. A neighboring rock outcrop shows the slide is formed on a front-slope of schist. Both cracking and shallow slides are the results of recent activation of deep-seated sliding movement.

Residents are constructing many hand-made check dams of gabion-type in gullies by themselves (Fig. 6 and Photo 10). Design of dams are drawn up by soil conservation officers. Stone material is obtainable on site. Internationally-aided cement and wire are supplied through Parbat District Soil Conservation Office. This work is thus considered a successful example of residents' self effort for land environmental protection. The efforts are, however, the measures only to shallow regolith slides and small debris flows along and in gullies, and are not effective for stabilizing deep-seated

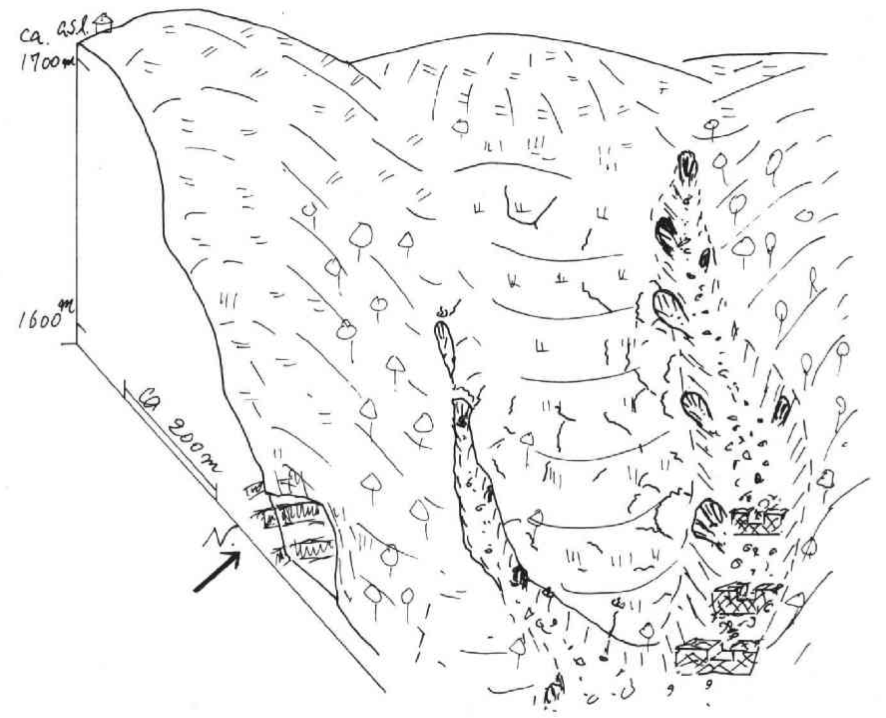

Fig. 6 An explanatory illustration of landform, geology, land-use, and deep-seated slide at Kuhire Kateri Samsire, Parbat.
Surface cracks and gabion-type check dams are shown. Other keys are the same as those of Fig. 4.

slides.

6 Discussion

From the viewpoint of soil and water conservation on hillslopes, paddy fields which are inevitably constructed almost flat at least in each lot are preferable in general to dry fields which are not necessary flat and then tend to induce overland flow and associated erosion, as estimated in a watershed in Mid-Western Middle Mountains (Kenting Earth Sci. Ltd., 1986). The positive evaluation of paddy terraces is, however, not applicable to the case of Smaili, in which paddy terracette construction promotes stripping off of very shallow soil resting on impermeable bedrock. Although farmers are aware of unsuitableness of the present land-use, they cling to the paddy terracettes which are important resources of favored food on rocky hillslopes even if their productivity is low.

In a deep-seated landslide zone as Banpali or Kuhire Kateri Samsire, paddy rice cultivation may accelerate the sliding movement due to increased infiltration. On the other hand, paddy rice cultivation is considered well-adapted use of a deep-seated landslide zone so far as the movement is kept so slow as not to destroy paddy terraces and incidental facilities, because deep-seated slide frequently produces relatively gentle slopes with thicker soil and plenty of surface and shallow subsurface water. It suggests the requirement of knowledge for the limit of paddy rice cultivation which does not accelerate sliding movement in a deep-seated landslide zone. The knowledge of sustainable use of a landslide zone may be obtainable from the investigation of water balance using a hydrogeomorphic process-response model which is experimentally set up in each landslide zone.

Before obtaining such knowledge, it may be advisable to convert paddy terraces in deep-seated slide zones to terraced dry fields associated with planting of trees with deep roots and high transpiration capacity. The advice is, however, hardly acceptable to most of farmers who have strong preference for and persistence in paddy rice. It seems to be more actual to introduce some cash crops than to propose any food for subsistence farming alternative to rice. Introduction of cash crops is advisable to Smaili farmers also, who have dry fields on relatively stable upper gentle slopes. Farmers who would decrease paddy rice cultivation for reduction of sliding movement could buy rice for the income from selling the cash crops. A problem is transport of the products to markets. Another problem is fluctuating price of cash crops, because low market price tends to cause renouncement of cultivation which induces devastation of land.

In any case, it is necessary to distinguish not only actively sliding sites but also potential landslide zones and areas affected secondarily. As described in previous chapters, it is remarkable that both residents and soil conservation officers tend to pay in most cases less attention to deep-seated slides which are moving slowly or moved formerly. Presentation of relevant information on potential geomorphic processes including deep-seated slides and areal extent of associated processes, for example mudflow, to residents and local officers is thus a matter of great importance.

The areas which have potential of various types of mass-movements can be indicated by systematic geomorphological survey in which airphoto interpretation and other remote sensing techniques, field observation and collection of records on previous hazards are effectively combined. Some pioneer works of hazard mapping in various areas of the Middle Mountains have been already presented. For instance, Land System Report (Kenting Earth Sci. Ltd., 1986) and Ives and Messerli (1989) referred to several maps showing geomorphic situation of mass-movements mostly of shallow regolith slide type, while Miyagi (1990), Saijo et al. (1990) and Yagi and Oi (1993) prepared maps focused on big landslides and debris flows. In addition to the effort of survey, it is required to develop the means by which the results of the survey are effectively communicated to planners, officers of various specialities and residents. Thus the information of potential geomorphic processes will be utilized not only for disaster prevention or hazard mitigation in narrow sense but also for planning of wise land-use.

Not only the hazardoussness of the site but also its effect to neighboring areas is a matter of great concern from the viewpoint of areal planning of sustainable land-use and environmental management. As mentioned previously in the Chapters 1 and 2, migration to valley bottoms within the Middle Mountains has been prevalent as well as longer-distance population movement towards Terai Lowland. The trend increases the probability of suffering damages from flood and mud/debris flow which are induced by various landslides in upstream areas (Tamura and Gyawali, 1996). A watershed provides suitable areal framework for the consideration of environmental management particularly in mountainous areas which contain many landslide-prone zones.

As shown in the first report by Nelson (1980), integrated watershed management plans and some related surveys in Nepal have taken erosion into consideration as an environmental factor which is intrinsic to the watershed and affects to the downstream areas through water and debris flux. Although Land System Report (Kenting Earth Science Limited, 1986) insists the overemphasis of man-induced soil erosion and underestimation of natural mass-movement in previous works in Nepal, it takes special notice of regolth slide and glacial dam outburst flood. The management plan of Phewa Tal watershed (FINNIDA, 1992) also makes reference to landslide under the heading of "soil erosion" and treats of only shallow regolith slide as well as other surface erosion processes and their consequence in filling of the lake. Significance of continueing deep-seated slide as one of the environmental characteristics existing together with human living seems to be thus overlooked.

The situation suggests that environmental management planning of mountainous watersheds must incorporate the information on landslides and related phenomena as well as land-use in slide-prone zones and adjacent areas. Land-use should be considered as not only the objective of the planning but also a factor of environmental processes. Farmers' preference of specific crops can be incorporated into the planning of watershed environmental management through evaluation of both the effect of their cropping to environment and their willing to maintain the cultivation which has certain effect on environment. For instance, persistence of paddy rice cultivation was effective for the sustainable use of a deep-seated landslide zone at Banpali till a few years ago, and recently changed to play a role of a slide accelerator, although the cause of the change remained unrevealed.

7 Concluding remarks

The Middle Mountains of Nepal abound with not only shallow regolith slides but also some other types of landslides, mostly according to their geologic and geomorphic conditions. Some of them occur in relation to land-use particularly terraced paddy fields. This paper has described some cases of interaction between paddy terrace construction/cultivation and a few types of landslides except ordinary shallow regolith slide.

In a case of paddy terracettes constructed on shallow impermeable bedrock slope, terracette construction and paddy rice cultivation on the terracettes inevitably promote stripping off of very shallow stony soil and induce debris flow which affect fields downslope. In other cases of paddy terraces constructed in deep-seated landslide zones which have been developed on particular geology or geologic structure, paddy rice cultivation is, on the one hand, one of the wise use of land condition produced by continuing slide and, on the other hand, accelerates recently the slide movement through increasing infiltration. In any case, both residents and soil conservation officers pay attention to ongoing surface phenomena only, and farmers' preference to paddy rice is strong.

The situation suggests that not only simple conversion of land-use to forest or other dry-field crops but also careful continuation of paddy rice cultivation with restricted intensity in a selected sites is more advisable as wise and sustainable use of areas prone to particular type landslides. Such advice, which is essential for management of watershed environment, should be associated with apprehensible information on type and intensity of movement as well as zoning of landslide. Systematic geomorphological and land-use survey and hydrogeomorphological analysis of the results will provide the information.

Acknowledgment

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This paper is dedicated to Professor Emeritus Hiroshi Shitara for the commemoration of his 70th birthday.

Notes

1) It was estimated from the census figures which were cited in several publications even though certain limitation was indicated.
2) Although usage of the terms *bari* and *khet* seems to be a little complicated as seen in Ives and Messerli (1989), Gilmour and Fisher (1992), Shar (1992), and FINNIDA (1992), they can be regarded as almost corresponding to terraced dry field and terraced paddy field, respectively, in the context of at least this paper.
3) Although the published land system maps of the area, scale 1/50,000, show both "Moderately to Steeply Sloping Mountainous Terrain" and "Steeply to Very Steeply Sloping Mountainous Terrain" in the Middle Mountains, they do not agree with actual alternating distribution of structurally controlled slopes as described in this paper. The difference seems to arise from the procedure of land system mapping depending too much on simple morphometry on toposheets, scale 1/50,000, which were photographically reproduced from one-inch one-mile sheets prepared originally by the Survey of India in the 1950s. Moreover, some misunderstanding of or deviation from the original or widely accepted concept of land system and land unit (Christian, 1958 ; Christian and Stewart, 1968) are noticed in Land System Mapping Project carried out by Kenting Earth Science Limited (1986) in Nepal.
4) VDC denotes Village Development Committee, the smallest local administrative unit in Nepal usually consisting of 9 wards.

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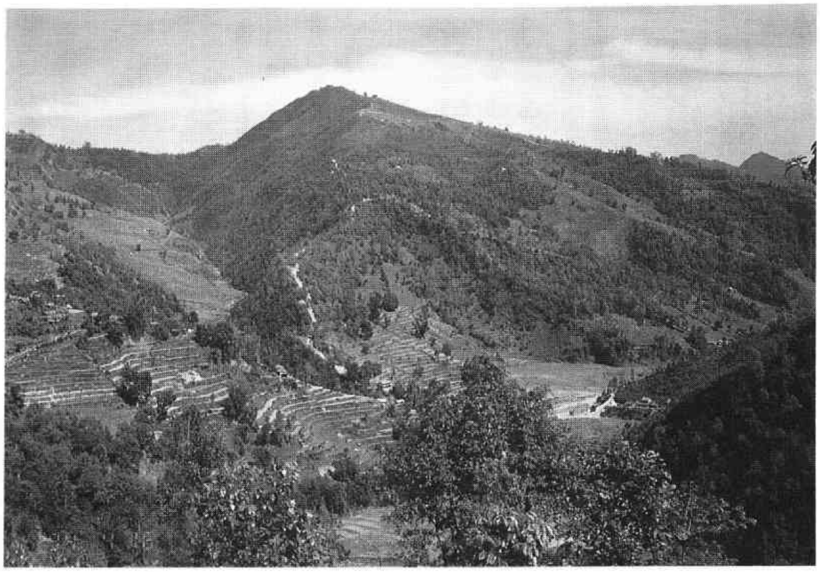

Photo 1 Structurally controlled slopes and differentiated land-use on them in the Middle Mountains, east of Pokhara. (Photo by T. Tamura ; April, 1994)

Photo 2 Concentrated regolith slides and debris flows on cultivated and forested hillslopes in the Middle Mountains, west of Kathmandu. (Photo by Tamura ; April, 1994)

Photo 3 The hillside covered by paddy terracettes, partly abandoned, at Smaili, west of Pokhara. (Photo by T. Tamura ; May, 1994)

Photo 4 Paddy terracettes and a rock-bed stream at Smaili, west of Pokhara. (Photo by T. Tamura ; May, 1994)

Photo 5 Recently constructed fields on floodplains and alluvial cones at the foot of Smaili, west of Pokhara. (Photo by T. Tamura ; May, 1994)

Photo 6 Relatively fertile paddy terraces with thick soil in a deep-seated slide zone at Banpali, west of Pokhara. (Photo by T. Tamura ; May, 1994)

Photo 7 A crack and a small shallow slide at its end on paddy terraces in a deep-seated slide zone at Banpali, west of Pokhara. (Photo by T. Tamura ; May, 1994)

Photo 8 Terraced paddy fields, mostly abandoned, in a deep-seated slide zone at Kuhire Kateri Samsire, north of Kusma. (Photo by T. Tamura ; May, 1994)

Photo 9 Cracks on abandoned paddy terraces in a deep-seated slide zone at Kuhire Kateri Samsire, north of Kusma. (Photo by T. Tamura ; May, 1994)

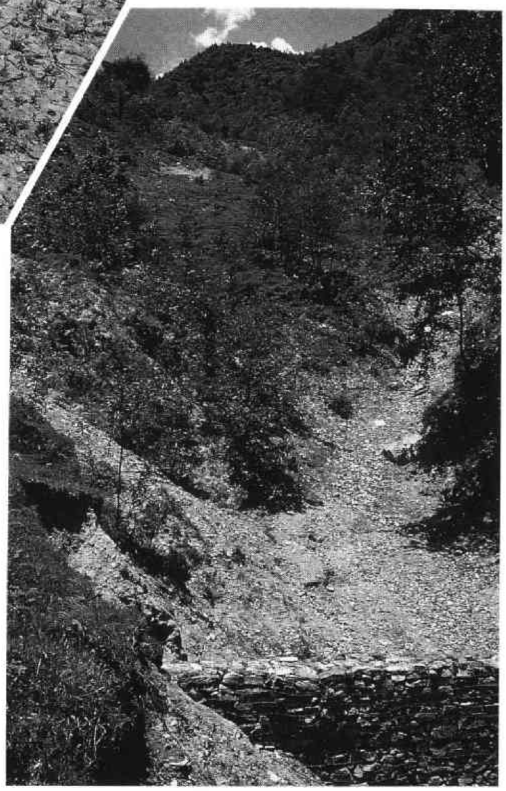

Photo 10 Shallow slides and a gabion-type check dam in a deep-seated slide zone at Kuhire Kateri Samsire, north of Kusma. (Photo by T. Tamura ; May, 1994)