SUSTAINABLE MANAGEMENT OF ALLUVIAL FAN AND RIVER TERRACE BY LOCAL PEOPLE: A CASE STUDY – RANGPO VALLEY, SIKKIM

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[An alluvial fan is a depositional landform at the confluence of a stream with heavy bedload, the size being proportional to the dimension of the concerned drainage basin. In mountainous regions, where cultivable lands are hardly available, large alluvial fans are often converted into agricultural terraces. A river terrace is an abandoned valley floor of an incised stream. This landform is also used by mountain-people for cultivation. In the Rangpo Valley of East Sikkim, there are a few alluvial fans and river terraces which had been formed during the past when the Rangpo Khola incised its previous valley floor to keep pace with the rising Himalayan terrain. These landscapes are used by local cultivators of nearby villages for the purpose of agriculture. The two of the alluvial fans studied here are dry and lie at a higher elevation than the present confluences of Ralong Khola and Danok Khola, as these two streams which bound the fans and the river terrace, also incised their previous valley floors much below the fan and terrace surface. The agricultural terraces constructed are curved and have opposite alignments of downward convexity and concavity in fan and river terrace respectively, as they follow natural trends of the landforms. The soils of both the landforms texturally belong to silt loam though the composition varies slightly. People using these landforms for their sustenance understand the importance of those landforms and do not disturb them in any ways other than practising rain-fed cultivation producing rice, makai, millet and mustard. The cultivated terraces are well maintained. The sustainable use and related management for maintenance of terraces have sustained the scope of using them through generations.

Keywords: *Alluvial Fan, River Terrace, Rangpo Valley, Incision, Sustainable Use]*

Introduction

Alluvial fans are conical or fan-shaped (Japanese fan) depositional landforms normally found at confluences of streams, where they meet their master-streams. The Rangpo Valley of East Sikkim has a few alluvial fans. This paper examines two of such fans and an associated river terrace in terms of their origin, characteristics and sustainable management as done by the local villagers.

Location

Normally, alluvial fans are observed at confluences of tributary streams, but the alluvial fans of the Rangpo Valley are located at much higher level at the end of

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a river terrace. Of the two fans studied the larger one is southeast facing and the smaller one is south facing. The fans are located between two right-bank tributary streams of the Rangpo Khola, namely, the Ralong Khola along western end and the Danok Khola along the eastern end. The Danok, however, flows at a distance from the fans, whereas, the Ralong Khola flows just along the edge of the larger fan. Under the present situation, the two fans may be referred to as:

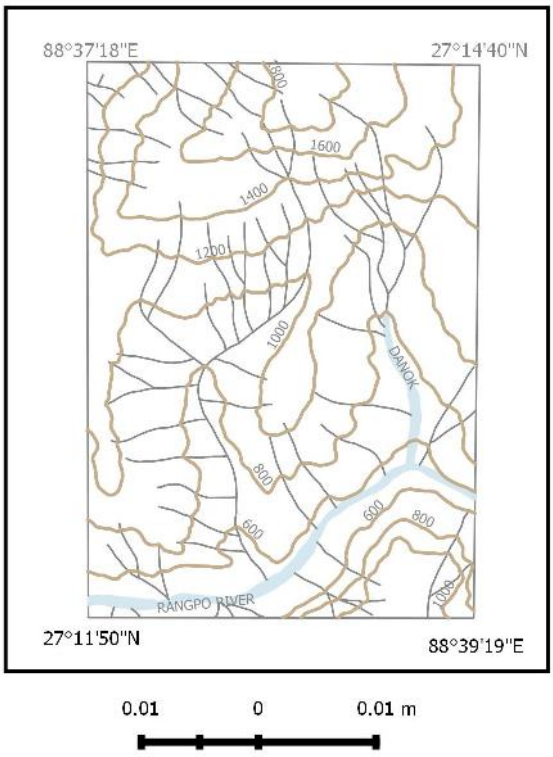
i) left-bank fan of Ralong Khola; and

ii) right-bank fan of Danok Khola.

The two fans are separated by a spur (Fig 1). At the foot of the spur, the two fan-ends coalesce with each other for a few metres of stretch.

Latitude and longitude wise the fan area may be marked as 27°11′50″N/ 88°37′18″E to 27°14′40″N/88°39′19″E in areal extent.

Figure 1 : Spur Separating the Two Streams and Two Fans



Origin of Alluvial Fans

Alluvial fans are formed by deposition of an excess amount of sediments which is much greater than the sediment load normally the mountain stream carries. It may not be a sudden influx of bed-load always. If the quantity of sediments

deposited is much greater than the master channel can wash out instantly, a fan may be formed. Blissenbach (1954) considers that sheet flood and stream flood are the two main causes for the formation of an alluvial fan. It may also form due to the change of a stream from a confined to an unconfined status as related to the change of topography. Kinghton in his book (1998) suggests that the three particular conditions mentioned by Blair and McPherson (1994) as optimal for the formation of alluvial fans are suitable depending on the particular situation of an area. These are: i) change of stream flow from a confined course in the mountainous or hilly upstream segment to a relatively flat topography in the downstream course; ii) plenty of sediments to be carried by the stream; iii) a climatic regime which causes extreme stream discharge and mass wasting to deliver the stream a suitable and huge sediment load required for the formation of alluvial fan. In the case of the Rangpo valley fans, stream flood is a strong probability as the cause of formation. In the geologic past, sudden increase in the bed load of streams of the area might have caused them throw the sediments along the slope in the down-stream part of mountain front where slope was gentler than their upstream part. The sudden increase in the bed load of tributary streams may be related to the occurrence of a deluge of rainfall under cloud burst or so, which is not unlikely for a humid mountainous region.

The larger fan, however, may be related to the depositional process of the Ralong Khola, whereas the smaller right bank fan of the Danok Khola does not have a source stream present in the area, because the source stream is rather obscured under the present landuse of homesteads and banana plants. May be the stream had been a very minor one which was filled up with the load of sediments and later encroachment by local villagers covered its identity.

Review of previous Literature about Himalayan Alluvial Fan

A study has been made by Subimal Sinha Roy (1976) on the formation of alluvial fans along hill slopes in the Rangit Valley of the Eastern Himalaya. He observes that 'the Daling Group of rocks composed mainly of phyllites' predominates his study area 'where the Gondwana sandstone is exposed in the Rangit tectonic window'. He also observes that in the broader middle and lower part of the Rangit Valley alluvial cones are formed. These cones or fans are composed of angular boulders, cobbles, and pebbles along with sandy materials at their base. Such alluvial cones are similar to that of the alluvial fans in the Rangpo Valley. In an identical way the loose materials of the fans remain in a 'critical state of equilibrium' at the slope of 'angle of repose'. This paper also observes that the human agency does not disturb such a limiting state of equilibrium for the fear of landslide disaster. In the case of the Rangpo Valley also, local people do not disturb the fan-slopes. Moreover, in a similar way, as the given photograph (Misc. Pub. GSI. 24) shows, the upper surfaces of the alluvial cones

are shaped into agricultural terraces. The management of the alluvial cones of the Rangit Valley by the local people is almost identical with that of the alluvial fans of the Rangpo Valley. This paper, however, being a research within the conventional boundary of geology and geomorphology does not stress on the management aspect of the alluvial cones studied.

Characteristics of Alluvial Fans

The two alluvial fans, i.e., the left bank fan of Ralong Khola and right bank fan of Danok Khola are much different in shape and size. Bull (1964a) considers an empirical relationship between an alluvial fan and its contributor drainage basin. According to him this relationship is based on an open hydrologic regime of basin area, as he observes that the size of a fan is dependent on the area source of sediment of the contributing basin. The relationship is expressed as

A_f = Size of fan

$_f = cA_b^n$ c = a numerical constant varying between 0.15 & 2.1

n = an exponent which is approximately 0.9

A_b = basin area

The coefficient 'c' varies widely due to the differences of some independent variables, such as lithology of drainage basin, its climate, its tectonic movements, as well as the size of the space on which the alluvial fan is deposited (Fairbridge, 1968).Favourable conditions ask for higher value of the coefficient. 'n' is less than unity because the discharge per unit area at a given frequency becomes higher in case of small drainage basins than in large basins (Hooke, 1965).

In the case of the fans under study, the lithology of the drainage basins is weak, as the rocks are mostly phyllites alternated with some arenites, both of which are highly susceptible to weathering. The arenites, however, are more resistant, in general. These rocks belong to the Gorubathan Formation of the Daling Group. The climate is humid mountain climate, a variant under monsoon regime. This part of the Eastern Himalaya is not tectonically stable and repeated uplift of the terrain under strain has been recorded (Valdiya, 2004). The episodes of uplift (1.0 mm in Siwaliks to 7±2 mm/yr) inspire streams to erode further and at a faster rate than before. The space available for throwing of the excess volume of sediments being a mountain front, in the case of the left bank fan of Ralong Khola, was small and eventually gave rise to a steeper and larger fan than the right bank fan of Danok Khola which was deposited on a gentler surface with lower elevation. The elevation of the apex of the Ralong Khola fan is 626m a.m.s.l. and of the Danok Khola fan is 594 m a.m.s.l.

When the areas are calculated by G.P.S. survey, it is 6686.438 sq. metre for the larger fan, whereas for the smaller one it is 5036.555 sq. metre. The perimeters are 449.553 metre and 345.795 metre and the axial lengths are 148.71 m. and 73.0 m. respectively. The area per unit axial length in the larger fan is 44.87 m^2/m and for the smaller fan 68.99 m^2/m, as the

former is more elongated in shape than the latter.

As far as slope of the fans are concerned, it is steeper in the larger fan than the smaller one. The gradient of slope in the larger fan is 424:1000 and in the smaller fan is 329:1000. Hooke (1965) considers that fans with steeper slopes have coarser grained deposit than gentler ones.

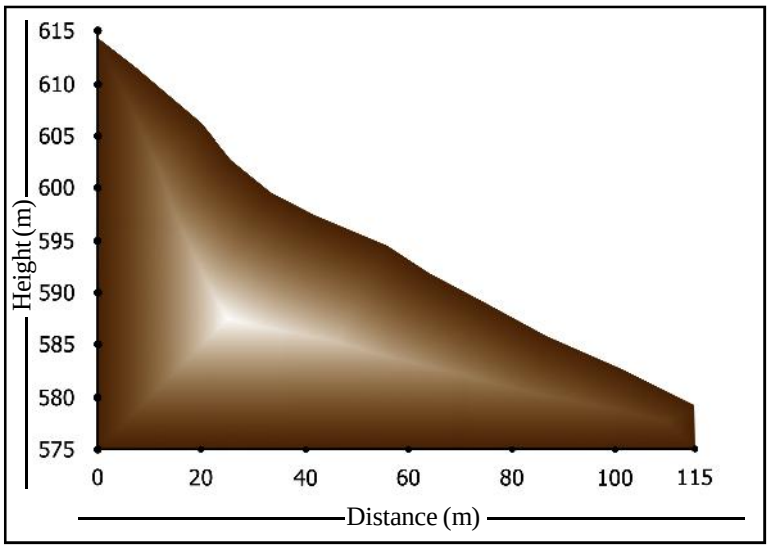
The materials examined reveal that the Ralong Khola left bank fan has coarser grained deposits than Danok Khola right bank fan and consequently the steepness of slope is greater in the former. The space of mountain front on which fans are formed is also steeper in the former than the latter.

The slope of the larger fan, however, is better expressed by a longitudinal topographic profile taken along the middle of the fan from top to bottom (Fig.2). This profile reveals that the slope of the fan is steeper in the upper segment, slightly depressed in the middle part, and gentler in the lower segment. The deposition of coarser particles at the apex area makes it steeper in the upper part, whereas the deposition of finer sediments in the lower segment makes the slope gentler.

Table 1

Distance (M)	Height (M)
0	614.0
7.5	611.325
12.0	609.385
19.5	606.145
25.5	602.775
33.5	599.540
42.0	597.395
56.0	594.330
64.0	591.830
74.0	588.990
86.0	585.995
101	582.725
115	579.255

Figure 2 : Longitudinal Profile of Larger Fan



Unlike most of the alluvial fans of humid mountains, these fans are dry as the tributary streams of the Rangpo Khola have incised their courses keeping pace with the down cutting of the Rangpo Khola at the face of the slowly rising Eastern Himalaya (Chowdhury, 2014), the rate mentioned earlier. The Ralong Khola along with incision has bypassed the alluvial fan with slight shift towards west. The incised course now flows along

the edge of the larger fan. The smaller fan is also dry as the minor contributing stream has vanished from the area. The only source of moisture for the fans, at present, is rain-water, which mostly occurs during monsoon months, along with some seepage water from uphill side.

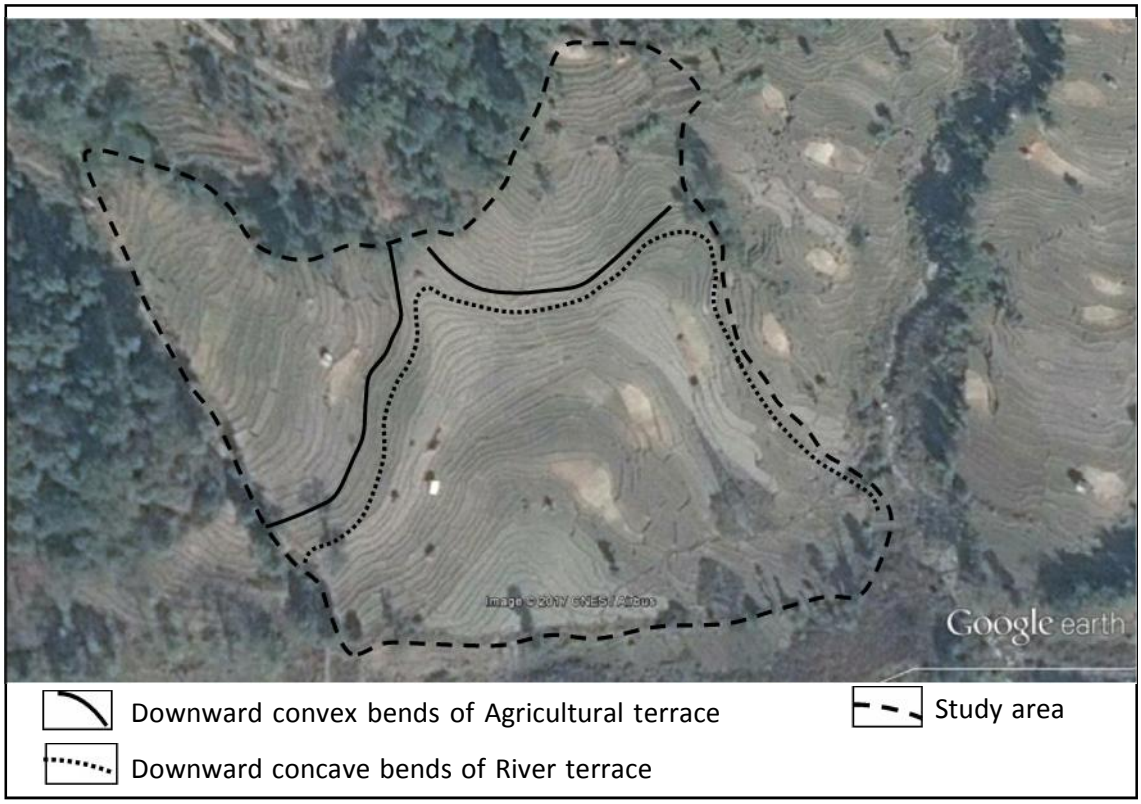
The alluvial fans merge into the right bank terrace of the Rangpo Khola. Usually, a river terrace is a flat (nearly flat) surface marking the abandoned valley floor (Morisawa, 1985). Had the previous channel been a matured one, sorting of deposited particles would be observed. In the case of the river terrace of the Rangpo valley, such sorting is present. Thus the mature valley floor of the Rangpo Khola has been abandoned and the stream has incised its valley to get a new course further downward at lower elevation. At present, the Rango Khola is eroding the toe of the left bank only.

Sustainable use of Fans and related Management

There are three villages at the immediate roof of the fans, namely, Amba, Tarethang and Takchung. The villagers of these three villages practically depend on the fan deposits and river terrace below it for their sustenance. They have terraced the fans for the practice of agriculture. Nature has made a further endowment toward them by the formation of river terrace resulting from incision and shifting of the Rangpo Khola and its tributaries. That has left a wide open river terrace stretching from the foot of the fans to the present course of the Rangpo Khola. The villagers when constructing their agricultural terraces on alluvial fans also constructed wider terraces on the river terrace, and the surface slope, in this part, was much gentler. Apart from their wider cross sections than fan-terraces, these terraces are marked with opposite curvatures compared to the fan-terraces. The agricultural terraces on fan deposits are convex downward, whereas on river terrace those are concave downward (Fig.3). This opposite trend of terraces follows the trend of curvature of the natural landforms; otherwise there is no logic in doing so. The alluvial fans radiate outward from their apex toward the mountain front and conversion of such a landscape through construction work becomes easier if the natural trend of slope is followed.

On the other hand, the shifting of the Rangpo Khola from the foot of the mountain toward south, i.e., toward the present course, naturally took a lot of time through a repeated course of channeling in new lands leaving point bars and meander scroll. Those curved features could have their natural concavity towards the channel, as well as much variability in micro relief. This concavity and variability of relief are reflected in the trend of agricultural terraces constructed on the river terrace of the Rangpo Khola. Why should people take more trouble in converting the natural trend of land, while following the direction of nature is an easier way to serve their purpose?

Figure 3 : Google Earth Image of Study Area



When the soils of the agricultural terraces on fans as well as river terrace are checked, it shows a difference in soil colour, soils of the fans are whitish and more clayey than soils of the river terrace which are brownish in colour. The soils of the fans have their composition favoured by phyllitic parent materials, as it is observed that the uphill side on the right bank of the Rangpo Khola has very long exposure of Garubathan phyllite which is weak and crushed into shiny white clay through weathering . It may be mentioned in this context that the road section from Rorathang bridge to Pakyong across the three villages has exposures of phyllite all along the hillside. That is the reason why the soils of the alluvial fans are more clayey and whitish in colour. When soil samples are tested in laboratory, the texture is silt loam as revealed in table 1 for textural composition.

On the other hand, the soils of the river terrace are formed in the river-borne silts which are composed of a variety of rock-dusts produced through fluvial erosion. Moreover, at lower elevations and

Table 1

Name of the sample	Weight (in gram)	Horizon	Percentage of			Textural Class
			Sand	Silt	Clay	
Right bank terrace	50.0444	0 to 15 cm	30.14	61.95	7.91	Silt Loam
Alluvial Fan	50.6046	0 to 15 cm	33.56	56.64	9.80	Silt Loam

channel depressions, the scope of accumulation of organic residue is high. This may be responsible for the change of soil colour on river terraces. The textural composition, as incorporated in table 1, indicates the soil to be silt loam again though the percentage of clay is higher in alluvial fan. The agricultural productivity, as known from local cultivators (Bimala Pourel, Tika Pourel and Monorath Kafle—Villagers of Tarethang), does not vary much between the two types of terraces, though in the years of weak monsoon, it varies substantially. During the years of weak monsoon, the fan terraces become drier than that of the terraces on river terrace, and as a result, produce much less quantity of crops. The river terrace being of gentler slope and low topography accumulates more water. The area, not having any major mountain spring, is dependent on monsoon rain for agricultural production. Mainly, three crops are grown, i.e., paddy, maize (makai) and mustard, and also kodo which is a millet used in the production local drinks 'chhang'. The average rate of productivity for grain crop is 20 mund of paddy and 30 mund of maize per acre. Winter crop, i.e., mustard is produced through irrigation and soil moisture.

So far labour charges are concerned, it is Rs. 300 per man/day and for the ox it is Rs. 600—700 per ox/day. For specialist labourers, who construct and repair agricultural terraces as well as arrange for irrigation, it costs Rs. 500 per man/day. Commercialization of agriculture has not been possible, though there is an acceptable subsistence basis.

Maintenance of Agricultural Terraces

The farmers of the three villages certainly know the importance of the alluvial fans and river terrace. They understand that these landforms are the endowments of the Mother Nature towards the poor villagers, so that they can survive and can maintain their livelihood. So they do not disturb or misuse those natural landscapes in any ways that may bring about the ruin of their usable lands through landslides and soil erosion. Hence they have constructed their homesteads outside and above those natural landscapes. Moreover, the unmetalled and newly constructed road connecting Rorathang, Pakyong and Rongli has made their accessibility and connectedness much better than the past—as the location of the villages has been on the roadside at present. However, as it appears from the agricultural terraces made by bench terracing (USDA, 1964) that the inhabitants of the villages,

mentioned above, have the concept of sustainability in their mind, because they are very careful about the maintenance of the terraces. The agricultural terraces on alluvial fans are horizontal. Moreover, each terrace is bounded by embankment as its edge. Thus the embankments along horizontal terraces act as contour bunding (Raychaudhuri, 1981), which is a soil conservation measure. Another important feature of the terraces is their inward or hillward slope of gentle inclination. This can also prevent soil erosion by running water, as an outward slope favours more soil erosion. Upward these terraces are gradually shorter in length, as the fan is also tapering towards the upslope areas. Moreover, the terraces on fans have variable width between the upslope and downslope segments, steeper the slope, narrower the width and vice versa. All these agricultural terraces on fan deposits suggest that though the local villagers have converted the natural landforms into agricultural terraces, they are cautious and careful about the life of the terraces and this attitude is nothing but a concept of sustainability.

Acceptance of troublesome movement along Hill Slope

The unmatalled road connecting Pakyong and Rorathang is very lengthy and commuting daily for the purpose of shopping is almost impossible for a person. Moreover, Rorathang is not a market-place. Rhenok is the nearest market and shopping centre, but going to Rhenok via Rorathang is a detour journey. Rather climbing down the mountain slope and crossing the river (Rangpo) through hanging bridge and going to Rhenok via Tintale Village is a good short cut. That is why the people of Tarethang, Amba, and Takchang climb down the slope and commute to Rhenok via Tintale, but at the same time they do not ask for a metalled road along the slope, so that the slope is not disturbed. Instead of that they stride down the slope along a very narrow RCC path of about 3 ft. or 1 metre width (Chowdhury, 2017). Their children going to the Junior High School at Lower Mulukey also follow the same path. All these trouble they accept only to keep the cultivable slopes safe and undisturbed. They know that the fan deposits and the river terrace are the only land resources, disturbing which can make their life vulnerable.

Conclusion

More than 3000 inhabitants of the three villages (Census, 2011) depend on these lands for their sustenance. With the uniqueness of management of natural landforms by intelligent conversion of the same into a usable landscape, the inhabitants of the three villages, Amba, Tarethang and Takchung maintain their livelihood, more or less, smoothly through generations as away from the din and bustle of modern towns and lustre of consumerism.

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