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Research Paper

Coefficient Analysis of the Alluvial Fan Surface Geometry: A Methodological Approach to Applied Geomorphology

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Abstract: *The alluvial fan is a depositional geomorphic surface at the foothills. Most of the alluvial fans in tropical regions are highly dynamic under wet climatic conditions and neotectonic environments. The fans of this region are covered with fertile top soils and deep forests. The soils attack people for agriculture in this region. Presently the continuously growing population pressure causes huge deforestation in these alluvial fan areas for cultivation which causes an accelerating rate of natural hazards like flash floods, landslides, and soil erosion that accelerate the dynamic nature of the fan surfaces. The coefficient analysis helps to understand the dynamic nature of the alluvial fan surface and thus helps to identify the hazard-prone area for planning purposes.*
Keywords: *Fan surface, Triangular shape, Circular shape, Serve area, No-serve area, coefficients.*

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I. INTRODUCTION

Alluvial fans are the landform of fluvial deposits. The sediments are deposited from the river catchment area of the mountain surface to the depositional lobe of the fan at the foothills. It is a continuous process of deposition that causes the dynamic nature of this geomorphic surface (Hack,1960; Danny,1967). Soils of the fan surface are highly fertile and attracting people to develop agriculture and its associated landuse on this dynamic surface. It is necessary to identify the dynamic nature of the alluvial fans for land cover and land use. Climate and neotectonics are the major controlling factors of fan deposition (Bull, 1977; Wasson, 1977; Schumm, 1977, 80; Nilsen et al, 1984; Church & Ryder, 1972; McPherson &Hist, 1972; Roed and Wasylyk, 1973). Structural Geology, natural vegetation, fluvial networks etc. are the other minor factors. With the variation of the controlling factors, the alluvial fans vary in their dynamic nature in their different parts. Presently there are no remarkable methods to identify and measure the dynamic nature of the alluvial fans. Coefficient analysis helps to identify and measure the dynamic nature of the different parts of the fan surface. The identification of different geometric shapes and the dynamic nature of the fan segments are the main objectives of this study to analyse the fan shape coefficients.

II. MATERIALS AND METHODS

Alluvial fans are developed in conical, lobate, arcuate, circular or semi-circular shape. All these shapes of the fan surface are developed in a radial manner that is composed of two geometric shapesie. atriangular shape and a circular shape (Fig: 1). These two geometric shapes are identified as ideal geometric shapes which do not match perfectly with reality. That means the ideal geometric shape and the actual geometric shape of the fan surface are not the same in real ground. The area of the ideal shape may be larger or smaller than the actual area of fan segments. First, the area of the actual shape and ideal shape of the alluvial fan surface has been identified and after that, the coefficients are determined.

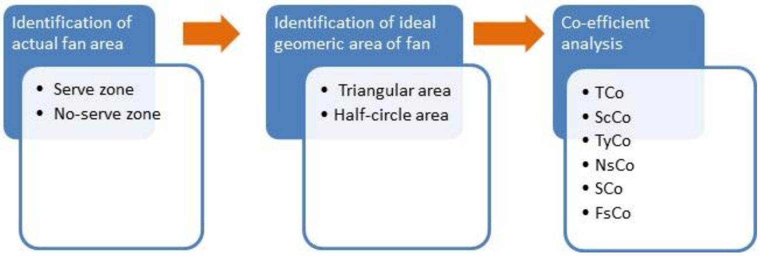

Figure 1: Methodological flow chart

2.1. Identification of the actual surface of an alluvial fan: When an alluvial fan radiates to the down slope then it stretches laterally. After a certain distance, the lateral extension is stopped and the fan area reduces its lateral extensions to the downslope causingan arc or semi-circular shape of the distal part of a fan surface. The semi-circular part shows an active lobe of deposition that causes continuous forward movement of the fan area. This part of the alluvial fan is a younger surface and is identified as an *active area or serve zone* (Fig: 1). The area above the active zone or the line of maximum lateral extension is an older fan surface and is identified as *passive area or no-serve zone* (Fig: 1). In this area of alluvial fan surface inactive or semi-active depositional lobes are observed.

2.2. Identification of the ideal surfaces of an alluvial fan: Alluvial fans are the combination of two ideal geometric shapes i.e. triangle and half circle. These shapes are determined based on some geomorphic properties of the alluvial fan like fan head, maximum lateral extension, distal margin etc. The fan head or apex is located at the debouching point of the river where it leaves its mountain course and starts the middle course. This point is identified as point **'A'**. The maximum lateral extension is observed, where the semi-circular shape of the alluvial fan has started. Points **'R'**&**'L'** are identified for the right and left wings respectively of the alluvial fan. The line **RL** represents the maximum lateral extension of the fan surface. The distal margin, which is semi-circular, is the maximum extension to the downslope of an alluvial fan. A centre point **'C'** is identified at the middle position of the line RL. Here the **CL=CR** (Fig: 1).

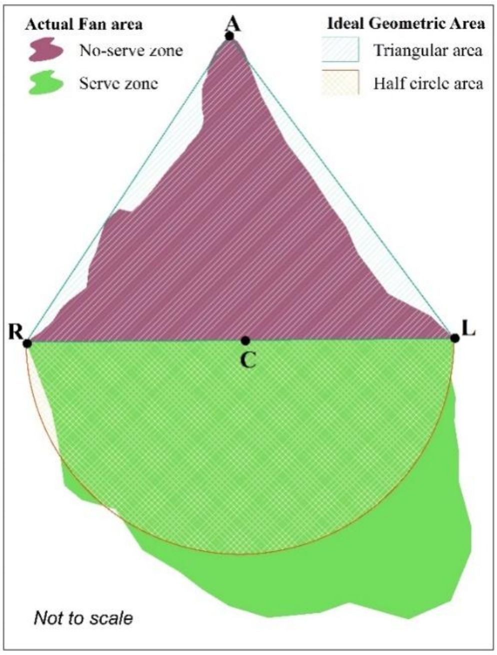

Figure 2: Index map of alluvial fan geometry

A triangle of **ARL** has been constructed over the older fan surface and a half-circle has been constructed with a radius of CL or CR over the younger fan surface. The triangle is considered the ideal shape of the old fan surface as a *no-serve zone* and the half-circle is considered the ideal geometric shape of the younger fan surface as a serve *zone* (Fig: 1).

First, the serve and no-serve zones of the actual fan surface have been identified and 2nd the ideal surfaces are identified and lastly based on the data of the 1st and 2nd steps the coefficients are derived (Fig: 2).

III. OBSERVATIONS AND ANALYSIS

The coefficient analysis is a measure of alluvial fan dynamics. The dynamic conditions are variable in different parts of an alluvial fan under different climatic and tectonic environments. The determination of coefficients needs to measure the geometric properties of an alluvial fan surface (Table: 1).

3.1. Triangular coefficient (TCo): It is the percentage (%) of the ratio of the actual area of the total fan surface to the ideal area of the triangular surface. This is used to identify the triangular fan shape.

$$TCo=(AaTfs/IaTs)\times 100$$

100% refers to an ideal triangular fan of a mature stage. This type of fan is developed on a steep surface of a stable tectonic environment.

<100% indicates an immature stage of alluvial fan. Lowering the value refers to lower maturity. The fan is moving towards an ideal triangular shape. Rejuvenation of regional slopes under neotectonic environments is responsible for this type of movement. Sometimes this value in the mature stage signifies the structural controls over the fan under neotectonic environments.

>100% signifies the dynamic nature of an alluvial fan. The mature fan is moving away from its ideal triangular shape. A higher value refers to the higher expansion of the fan surface beyond its mature stage. Lowering of regional slope due to neotectonics or upstream rejuvenation due to climatic change or both are responsible for this type of fan movement.

Table: 1, Geometric properties and index

Geomorphic properties	**Index**
Actual area of No-serve zone	AaNsz
Actual area of Serve zone	AaSz
Actual area of Total fan surface (AaNsz+AaSz)	AaTfs
Ideal area of Triangular surface	IaTs
Ideal area of Half circular surface	IaHcs
Ideal area of Total geometric surface (IaTs+IsHcs)	IaTgs

3.2. Semi-circular coefficient (ScCo): It is the percentage (%) of the ratio of the actual area of the total fan surface to the ideal area of the half-circle. This is used to identify the semicircular fan shape.

$$ScCo=(AaTfs/IaHcs)\times 100$$

100% argues for an ideal circular fan of the mature stage. A gently sloping surface under a stable tectonic environment is responsible for this type of fan shape.

<100% refers to an immature stage of an alluvial fan. A lower value indicates the higher immaturity of the fan that is moving towards an ideal circular shape. Lowering of regional slope due to neotectonic is responsible for this type of movement.

>100% signifies the dynamic nature of an alluvial fan. The mature fan is moving away from its ideal circular shape. A higher value refers to the higher expansion of the fan surface beyond its mature stage. Rejuvenation of regional slopes under neotectonic movement or upstream rejuvenation due to climatic change or both are responsible for this type of fan movement.

3.3. Typical coefficient (TyCo): Typical fan shape is the combination of triangular shape and circular shape. The combined effect of more than one controlling factor forms this alluvial fan. Climate and neotectonics are the dominant controlling factors of fan development. When the other minor factors i.e. vegetation, structural geology, land cover land use etc. gradually become dominant then the typical fans develop.

TyCo is the percentage (%) of the ratio of the actual area of the total fan surface to the ideal area of the total geometric surface.

$$TyCo=(AaTfs/IaTgs)\times 100$$

100% refers to an ideal-typical fan shape of the mature stage of the graded environments. <100% indicates the fan's movement towards the ideal-typical fan shape and >100% indicates the fan's movement away from the ideal-typical fan shape.

TCo, CCo&TyCo are more appropriate for triangular, circular & typical fans respectively. To understand the actual fan surface geometry first, it is necessary to calculate all the coefficients (TCo, CCo&TyCo). The calculated value that is nearest to 100% would be considered as the present geometric shape of the fan surface. Among the other two values, greater than the nearest value would be considered the previous geometric shape, and lower than the nearest value would be the probable future geometric shape.

3.4. No-serve coefficient (NsCo): It is the percentage (%) of the ratio of the actual area of the no-serve zone to the ideal area of the triangular surface.

$$NsCo=(AaNsz/IaTs)\times 100$$

100% represents an ideal shape of the older fan surface. This situation refers to the stable condition of the fan. The fluvial deposition has been completely stopped in this area. This means that dynamic characteristics of the fan surface are absent here.

<100% refers to an unstable geomorphic surface. Active depositional lobes or active erosional surfaces are observed here. Active sediment supply from the catchment area causes active depositional lobes and upliftment of this area due to local neotectonics causes an active erosional surface in this area.

>100% value is observed when the old depositional lobes become active due rejuvenation of this older part of the alluvial fan. Structural controls under neotectonic environments cause this type of instability.

3.5. Serve coefficient (SCo): It is the percentage (%) of the ratio of the actual area of the serving zone to the ideal area of the half circle.

$$SCo=(AaSz/IaHcs)\times 100$$

100% indicates an ideal shape of the younger fan area under a graded condition. This refers to the mature stage of the younger part. The depositional lobes gradually become inactive and result in dynamic situations diapers here.

<100% refers to the dynamic nature of the fan surface. The depositional lobes are very active in this situation. This younger surface is developed after the mature stage of the old fan surface. Lower the value refers to the younger surface.

>100% indicates the development of younger fan surfaces under a forceful environment of either climate or neotectonics or both. In this case, the younger surface extends beyond the ideal half-circle area. A higher value refers to higher forceful environments of fan development.

3.6. Fan shape coefficient (FsCo): It is the percentage (%) of the ratio of the actual area of the no-serve zone to the actual area of the serve zone. This coefficient is suitable to identify the stage of fan development.

$$FsCo=(AaNsz/AaSz)\times 100$$

<100% represents a younger stage of fan development due to the steep slope of the fan surface. Numerous active depositional lobes and very fast fan propagation are observed in the serve area.

100% advocates for the middle stage of fan development that shows mostly equal amounts of depositional lobe both in the serve and no-serve zone of the fansurface.

>100% represents the mature stage of the fan surface that shows very low active depositional lobes in the no-serve zone of an alluvial fan.

IV. CONCLUSION

Foothills are rich in fertile soil that attracts people mainly in the wet climatic region. The continuously increasing pressure of population is changing the land cover and land use pattern in this area. The coefficient analysis of the fan surface geometry depicts the area of sediment movements over the fan surface and foothills. As a result, it is easy to implement a planning programme in the foothill area.

The analysis of coefficients helps to understand the dynamic nature as well as the stage of development of an alluvial fan. As a result, the coefficients will make planning for an alluvial fan easier. The TCo, ScCo and TyCo will help in the planning of a large region like foothill areas and the NsCo, SCo&FsCo will help in the planning of a small region like a single fan surface.

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