

GIS ADDED METHODOLOGY FOR MOUNTAIN LAND EVALUATION

Krishna Prasad Paudel¹

Abstract:

To reduce the jeopardized man-land interrelationship sustainable management of resource utilization is the must. The proper identification and delineation of available production potential of land provide the fundamental background to the rational planning strategy. Different land evaluation methods and techniques are developing to identify the production potential of land. The land characteristics and production potential are basically determined by its bio-physical, socioeconomic and cultural factors. In many respects, land evaluation techniques are developed as an area specific condition. In the mountainous region, specifically in Nepal, the slope inclination, soil depth and stoniness or rockiness parameters are basically considered in different suggested land evaluation techniques. Altitude, temperature, and precipitation are considered as modifiers. These procedures are basically very sound in theory but in practical point of view they have lot of complexities. To overcome these problems automated computer based GIS software can be applied. This technique is more accurate and reliable as well as time efficient in large area evaluation but needs to have more intelligent mind and accurate database.

Issues:

Under-nutrition or starvation of millions of people in the Mountain Regions of Developing Countries today emerge through a number of factors. Degradation of productive capacity of agricultural land and forest resources by mismanagement are the most alarming causes (Kelley, 1983:9). Soil loss is perhaps the most visible devastating factor that threatens millions of hectares of land, people and properties.

Land is the basis of endeavor to fulfill people's need for food, clothing, shelter and energy, serving in addition as the supplier of amenities concerning fields, landscapes and forests. It is for these reasons that since time immemorial land has been recognized as having special importance, properties and value (Davis, 1976:3).

Of the 13 billion hectare of the total land area of the world, only less than half is suitable for agriculture including grazing. An even smaller fraction - about 1.4 billion hectare - is at present suited for crop cultivation. This kind of useful land is not distributed across the region uniformly, in the Asia and Pacific region, the share is very small. Out of the total, 22.9 percent land is confined in this region and only 14 percent of that share is suitable for the crop growth (FAO, 1976). Specifically the Developing Countries with mountainous terrain have very miserable situation where nearly two-third population of the world are sharing their fate.

To reduce the jeopardized man-land interrelationship sustainable management of resource utilization is the must. The proper identification and delineation of available production potential of land provide the fundamental background to the rational planning strategy.

Since 1970s different approaches and techniques are developed for land evaluation. The first detailed project procedure was established by FAO (1976) and following works are adopting that procedure as a guideline. The land characteristics and production potential are basically determined by the bio-physical, socio-economic and cultural factors. In many respects, land evaluation techniques are developed as an area specific condition. In the mountainous region, specifically in Nepal, the slope inclination, soil depth and stoniness or

¹ Lecturer, Central Department of Geography, University, Kirtipur, Kathmandu. Author expresses sincere thanks to Dr. G. B. Thapa and I. P. Tiwari for their valuable comments.

rockiness parameters are basically considered in different suggested land evaluation techniques. Altitude, temperature, and precipitation's are considered as modifiers. Conventional technology and cultivation practices of local people and accessibility to market are not considered in these techniques. For the land use planning perspective, specifically in the mountain terrain, land evaluation technique also requires to analyze socio-economic, cultural, traditional and farmers' perception and technology which provide a great impact on land evaluation, judgement for allocation of crops and farming methodology.

Bio-physical, socioeconomic and cultural set-up of mountain terrain are quite typical. The Land evaluation activities of mountain region need to integrate these attributes to general land evaluation framework. The aim of this paper is to discuss an integrated land evaluation approach and its application in mountain environment of Nepal.

Mountain Environment:

Mountains occupy about 15-20 percent of the world's land surface and provide the life support base for about 10 percent of the world's population (Ives, 1989:289-345). Most of these highlands, be these the Himalayas, Andes, African Highlands, Rocky Cordilleras, or European Alps, have fragile ecosystems and poor agricultural potentials. Because of these, many Asian, African and Latin American Mountain slopes are carved by the poor inhabitants for their bare livelihood. In the case of Nepal Himalayas more than two-thirds of population of the country (19.3 million in 1991) are living in altitude more than 300 m to 4000 m (a.s.l) and they are extending their farmland on greater than 45° hill slopes (Poudel et al, 1989:256-267). Besides Nepal Himalayas, North India, African Highland, Latin American Highlands, and South-east Asian Highlands have also tradition of cultivating in the steep hillslopes.

Farming system, cropping pattern, land preparation technique, land management and crop types have great variation on the mountains than flat slope (Thapa and Weber, 1990). Soil-moisture condition and slope instability can play a vital role on land utilization system. Even, over the physically suitable land, peoples's attitude, perception, personal judgment, investment capability, tradition, culture and social obligations give the significant influence (Blaikie et al, 1982; Ives and Messerli, 1989). Therefore, mountain landscape and landuse systems are quite typical and area specific.

Land Evaluation:

Land evaluation is developed as a structured method to satisfy the need for information on present and potential uses of land resources for future planning (Putte, 1989: 139-142). In the process of land evaluation, FAO (1976) proposes a land evaluation project as:

- How is the land currently managed, and what will happen if present practices remain unchanged?
- What improvements in management practices, within the present use, are possible?
- What other uses of land are physically possible and economically and socially relevant?
- Which of these uses offer possibilities of sustained production of other benefit?
- What adverse effects, physical, economic or social, are associated with each use?
- What current inputs are necessary to bring about the desired production and minimize the adverse effects?
- What are the benefits of each form of use?

According to FAO (1976) Framework for Land Evaluation, economic and social analysis follow a qualitative land classification in two-stage approach; analysis of land and land use relationships proceeds concurrently with economic approach and social analysis in parallel (Davidson, 1980:31). In the integrated approach, topography, soils, vegetation,

geology, geomorphology and climate are considered as major variables and also used in land evaluation (Davidson, 1980:47).

Land evaluation is essentially concerned with land and neutral with respect to people (Diepen, 1982 cited in Putte, 1989) but Vink (1975) has emphasized on the artificial or man made features. Furthermore, it is emphasizing on the evaluation for land use planning (Putte, 1989:189-142).

Land has neither a single physical property like topography, soils, climate, drainage nor just socio-economic variables. From the resource analysis point of view some of those have 'stick' variables and some others have 'flow' variables. The land evaluation approach needs to cover both of these variables and the existing physical and socio-economic circumstance. But to bring these whole things into a single composite form, land evaluation needs a sound methodological basis.

Land Classification System:

Land evaluation simply means assigning a value to a specified unit area of land. Land should be rated on its value for a specific purpose, since there is no absolute and general applicable value of land (Beek and Beennema, 1974:60, cited in Townshend, 1981:9). In practice, the final expression of this value will be in economic terms (Nix, 1968:77, cited in Townshend, 1981:10).

In a land classification system, different land suitability order, class and sub-classes are designated by rating value according to the FAO (1976) land evaluation framework. Soil, moisture, nutrients, climate and topographic variables are considered. In this framework the major difficulty remains on value assigned for rating a particular parameter. Quantitative judgement for rating an individual condition can mislead the zonation of assigned class.

Review of the Suggested Land Evaluation Systems for Mountainous Terrain of Nepal:

The biophysical situation of land and its socioeconomic condition is drastically different from developed and mechanized agricultural countries. Therefore, the land evaluation systems developed in United States and levelled terrain can not be directly applied in the Nepalese hill agro-ecosystem (Shapit, 1987:6). In this perspective, different land evaluation systems have been suggested for the mountainous terrain of the country.

Phewa Watershed Land Capability Classification:

A modified version of land capability classification system of Mac Sa Project Thailand has been adopted for the land classification system of Phewa Watershed (in part, 1980). The classification was based on parent material, soil depth, rock outcrop, slope, runoff class and one of limitations related to stoniness, wetness or occasional flooding and severe erosion. On the basis of these parametric classification procedure, about 122 km² area of the watershed has been divided into eight capability classes as i. cultivable without terracing, ii. cultivable with terracing iii. cultivable with terracing essential, iv. pasture, v. fruit tree, vi. forest land, vii. silviculture, and viii. protected forest.

This system has not considered the existing terracing system, which is extensive and is a major factor determining the land capability classes in Nepal.

The Land Resource Mapping Project (LRMP) Land Capability Classification:

The classification is based on the effects on combinations of soils, landform characteristics and climate. Soils, physiography, climate, geology and geomorphology have been integrated into the framework of Land System Mapping, which is the basis for the Land Capability Classification (LRMP, 1986a, 1986b).

The land system map provides baseline information on landform, soil, geologic material and climate at a scale of 1:50,000. It is a hierarchical mapping system differentiating land characteristics at various levels of detail as:

Region Level: Physiographic, geology, geomorphology,

Land System: Recurrent pattern of landform, geologic material, slope and arable agricultural limit.

Land Unit: Landscape features-position, slope, degree of dissection, flooding, soil characteristics-Drainage, depth, texture, pH, profile development.

It provides a probability of finding a suitable or likely problem of a specific feature or use at national or regional level.

This system is used for all over the country. There are some limitations in its application aspects. The Land Capability Map indicates only options for farming and other uses including management requirements. It is not intended for growing specific crops or specialized tree or fruit crops for which interpretation may again be made from original Land System Map separately. This system does not consider the extensive man-made level terraces, which is a major factor determining the capability classes in the country. Slope correction due to terracing definitely upgrade the landuse capability of the land. The system has very broad slope categories and has not considered the soil limitation factors due to stoniness or rockiness.

Land Capability Classification System for Nepal (1987):

A composite form of landuse land capability classification system for Nepal has been suggested by Sthapit (1987). This is based on overlay interpretation of four base maps, such as:

- i. Climatic map
- ii. Landuse map
- iii. Landform map including slope, and
- iv. Soil map including soil depth and stoniness or rockiness.

Generally, three levels of planning as reconnaissance, semi-detailed and detailed and three levels of generalization of mapping systems as, Level I (1:250,000), Level II (1:50,000), and level III (1:10,000) are prepared for each level of planning. According to these bases he has suggested certain legend or land use, landform, slope class, soil depth, stoniness and rockiness classes for land capability classification.

Interpretation is based on the types of optional use, the relative degree of production potential, limitations and conservation measures for landuse, risks of soil damage and erosion hazard (susceptibility to water erosion). Nine different land capability classes are assigned to a land unit on the basis of the land's three main characteristics i.e. slope, soil depth and stoniness or rockiness. Terracing, fertility, texture, wetness, flooding, erosion, are assigned as modifiers. In assigning the classes, some assumptions were taken into consideration.

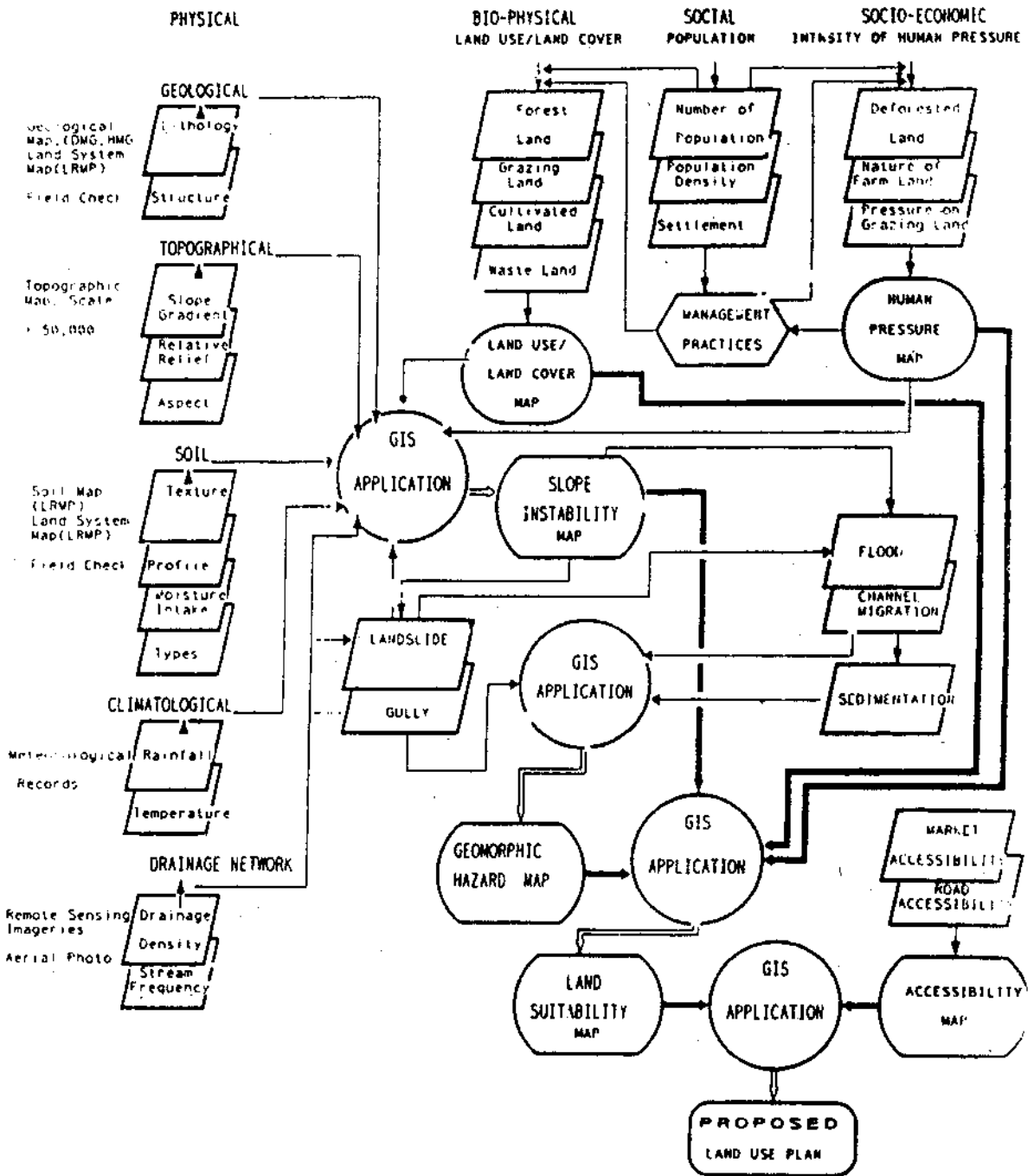
Although this classification system was basically designed for hill slope agro-ecosystem, it has some shortcomings to overcome the real evaluation problems. Thus it is not considered the management practices of the local farmers, productivity of agricultural crops and accessibility of road and market facilities. Rather it is suggested for the country level but the various parameters of the system need detailed field work and intensive survey which may not be feasible to implement at that level.

Application of GIS for Mountain Land Evaluation:

The term 'GIS' is currently applied to computerized information, synthesis and processing, modelling, analysis, display and retrieval systems that comprise hardware and software.

GIS is much more than just a means of loading, storing, and retrieving data about aspects of earth's surface. By the application of GIS, data can be assessed, transformed and manipulated interactively in such a system that they can serve as a test bed for studying environmental processes or for analyzing the results of trends, or for anticipating the possible results of planning decisions (Burrough, 1992). On the many technological and conceptual approaches to spatial data analysis, GIS has been widely recognized as the most

A MODEL FOR THE APPLICATION OF GIS ON MOUNTAIN LAND EVALUATION



promising tool capable of providing reliable information for decision making tasks (Michalak, 1993).

A parcel of land can have fourfold components such as;

(i) physical, (ii) bio-physical, (iii) social, and (iv) socioeconomic.

Different components have several variables and properties with diversified nature. On the whole, the data set of these properties can be separated into two groups and four types as;

- i. discrete - nominal and ordinal
- ii. continuous - interval and ratio.

In the GIS assisted program these data sets can be organized into a single format.

Manual overlaying and interpretation work for heterogeneous information and maps can not provide the reliable result. Human error on identification regional differentiation and boundary delineation may mislead the outcome, But these problems can be minimized by the help of GIS technology. The GIS techniques can integrate the diversified database acquired by different department in a composite form. It can reduce the cost for data acquisition and integrate the inter and intra-departmental organization of national as well as regional level planning perspectives. Therefore, land evaluation tasks needs to follow the GIS added methodology.

Mountain land evaluation needs to consider several attributes of both bio-physical and socioeconomic components and their numerous properties into a composite form. In this perspective different components and several variables can be organized into a single composite form and analysis can be made according to the objectives under consideration. According to this perspective a model for mountain land evaluation has been proposed (Fig. 1).

The task of land evaluation depends on the available database. Once used database may not be static for a long time. The accurate and precise evaluation needs an updated database. Field survey and measurement of all these databases is highly time consuming and expensive. Therefore, data storage, retrieving, manipulation and analysis function in computer based software is highly beneficial. These sorts of functions cannot operate in the manual as well as other system of analysis. Data retrieval, updating and manipulation provide the easy access to available database when change detection can be made very quickly. Some of these procedures can be integrated with the Remote Sensing database in Raster form. All these procedures provide very quick and efficient handling of the diversified origin and characteristics of database.

Computer based GIS analysis function can be used for various uses. Land evaluation exercise can be conducted by the assessment of physical and socioeconomic characteristics of land, different processes operating on that particular parcel of land, and the degree of suitability of that land for human activities. Because of easy access on database, quick and reliable analysis, precise and accurate analysis and time efficient provisions in computer based GIS technique it is very useful for land evaluation task.

GIS is not an inherent knowledge based program. It needs an accurate input with good operation. Therefore, the accuracy in GIS output is basically determined by the database used for analysis, input procedures, manipulation and analysis. Furthermore it depends on the capacity of hardware and the capability of software program under use.

Conclusion:

Mountainous topography has very low production potential, therefore, people living on the mountains have been facing serious food shortage. Due to this situation, man-environment interaction is jeopardised enhancing the down spiral role of development. In such context the most vital alternative should be to increase the production potential of the land. The evaluation of the production potential of land is the fundamental step for the management of the land resources. In this direction land evaluation framework has been

developed by FAO (1976). According to this framework land evaluation techniques are developed in different countries, but the methods and techniques of evaluation are country and area specific.

In the mountainous terrain specifically in Nepal land evaluation techniques suggested by different sources are typical in terms of factors and attributes taken into consideration. The major land classes suggested for Nepal are based on the soil depth, slope inclination and rockiness or stoniness. On the basis of these factors land use is suggested by the production potential of land, soil erosion hazard and suitability of particular crops. Altitude, moisture and temperature are considered as modifiers. Some of the basic factors such as productivity of crops, farming practices of the people and accessibility to market are not considered in these techniques which needs to be considered in the future. Most of these features are rapidly changing with time. Therefore, change detection in database system is necessary for the evaluation task. Computer based GIS software is the best alternative to access these facilities, where all of these components can easily be analyzed.

References:

- Blaikie, P, Cameron, J, and David Seddon, 1982, Nepal in Crisis, Delhi, Oxford University Press.
- Burrough, P.A. 1992, "Development of intelligent Geographical information Systems" International Journal of Geographical Information Systems, Vol. 6, No.1, pp.1-11.
- Davidson, Donald A., 1980, Soils and Land Use Planning, London and New York, Longman.
- Davis, K.P., 1976, Land Use, New York, McGraw-Hill.
- Diepen, C.A. Van, 1982, Evaluating land Evaluation, Wageningen International Soil Museum Annual Report,
- FAO, 1976, Land Evaluation Framework, Rome.
- Inpart, P., 1980, Phewa Watershed: Soil Survey Interpretation and Land Capability, Integrated watershed Management, Department of Soil Conservation and Watershed Management, Kathmandu, Nepal.
- Ives, J.D. 1989, "Mountain Environments", In: Study week on: A Modern Approach to the Protection of the Environment Nov.2-7, 1987, G.B. Marini-Bettolo (ed.), Pergamon press.
- Ives, J.D., and Bruno Messerli, 1989, The Himalayan Dilemma: Reconciling Development and Conservation London, New York, The United Nations University, Routledge,
- Land Resource Mapping Project (LRMP), 1986a, Land capability Report LRMP, HMG/N, Government of Canada and Kenting Earth Science Limited, Kathmandu.
- Land resource Mapping Project (LRMP), 1986b, Land Utilization Report, LRMP, HMG/N, Government of Canada and Kenting Earth Sciences Limited, Kathmandu.
- Messerli, Bruno, 1986, "Stability and Instability of Mountain Ecosystems" In: Integrated Mountain Development Tej Vir Singh and Jagadis Kuar (eds), New Delhi, Himalayan Books, Pp.131-140.
- Nix H.A., 1968, "The assessment of Biological Productivity" In: Land Evaluation. Paper of a CSIRO Symposium Organized in cooperation with UNESCO. 26-31 August 1968. G.A. Stewart (ed), Macmillian of Australia, pp. 77-87.
- Putte, Robert Van de, 1989, "Land Evaluation and Project Planning" ITC Journal, No. 2 pp.139-143.
- Poudel Krishna P., Krishna, K.C. and Kedar Basnet, 1989, "A Study of Hillslope Terrace Cultivation: Begnas Watershed Kaski, Nepal", The National Geographical Journal of India Vol. 35, No.3-4, pp 256-267.
- Kelley, H.W., 1983, Keeping the Land Alive: Soil Erosion - Its Causes and Cures, Rome, FAO,

- Michalak Wieslaw Z., 1993, "GIS in Land Use change Analysis: Integration of Remotely Sensed Data into GIS", In Applied Geography, Vol.13, pp.28-44.
- Mitchell, Colin W., 1973, Terrain Evaluation, Longman.
- Sthapit, K.M., 1987, Land Capability Classification, Watershed Manual No. 4, Department of Soil Conservation and Watershed Management, Watershed Management Project Nepal, HMG, Nepal, UNDP, FAO, Kathmandu.
- Thapa, G.B., and Karl E. Weber, 1990, Managing Mountain Watersheds: The Upper Pokhara Valley, Nepal, HSD Monograph, 22, AIT.
- Townshend John R.G.(ed.), 1981, Terrain Analysis and Remote Sensing London, George Allen and Unwin.
- Vink, A.P.A., 1975, Land use in Advancing Agriculture, New York, Spring-Verlag.