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MONITORING LAND USE CHANGE: Use of Remote Sensing and GIS

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Abstract

Land Use patterns reflect the nature of economic activity as well as natural resources of a country. The evaluation and assessment of land uses leads to diagnose the patterns of resources of a country which can further be developed in order to gain and maintain self sufficiency in the resources needed for human and economic development. The monitoring of land use change is highly difficult and complicated process due to its nature of spatial and temporal characteristics. Traditionally, ground surveys have been carried out to assess the land use patterns; however, the advancement of remote sensing techniques has lead to the evaluation of land use patterns in a very short time with high accuracies. The GIS techniques are very helpful to monitor the land use patterns as well as the future forecast of land use change precisely which lead to the sustainable development of resources of a country. This paper presents the use of Remote Sensing and GIS in monitoring land use change.

Introduction

Land use of an area on the globe reflects the patterns of natural and human environment. In term of physical environment, it varies from natural topography to Land cover classification as well as water and other natural resources of an area. On the other hand, it also focus and narrate the human activities which had been carried out in the past such as urban structure and major routes, to most recent human activities such as agricultural Land use, road transport network, urban development and industrialization etc. in an area.

Amongst various land uses agricultural land use has been the most commonly studied activity by the scholars. Stating from the early 19th century when von Thunen focused on the relationship of agricultural land use and transport cost to present studies by Harvey, 1966; Mattingley,1972; Symon, 1978 and Visser, 1980. Focus has been changing with the passage of time from transport cost to other factors such as socio-economic and behavioural factors (Ilbery, 1978) with respect to agricultural land use change. Scholars like Blaiki,1971 and Binswanger, 1987 have been trying to explore the factors affecting agricultural land use change. Several other scholars (e.g., Datoo, 1978; Grigg, 1979) have also been writing to explain the intricate process of land-use change.

Population growth has been considered one important factor of land use change. Ruthenberg, (1976), provided a valuable framework to understand factors influencing land-use change in this regard. Critics like Downs,1991; Geertz 1963 and Robinson, 1991, 1993 have been focused the role of policy and technology in an appropriate land use system for a country. A number of researchers (Allan, 1986; Chisholm, 1979; Harvey, 1963; Muth, 1961) have also emphasized on equally important role of infrastructure, including transportation facilities in land-use change.

The interaction of physical & human factors are so complex that study of Land use change in an area becomes highly technical and time consuming. A number of efforts (Coppock, 1978; Mather, 1986 and Rhind & Hudson, 1980) have been made to record the land use patterns. However, the nature of efforts have been changing with the advancement of technology. Historical land use surveys (Stamp, 1940s) had been involved the immense skilled and unskilled labour force which was ease out with the development of aerial Photography in 1960s. Aerial photography had been an important

data source for detecting land use patterns (Avery,1966 and Collins & El-Beik,1971). Recently, advancement of satellite systems has made it much easier to collect information regarding the Land use patterns of an area (Haris & Longley, 2000). However, ground truthing is still the core issues of all latest techniques. Previously, land use maps have been drawn to show the land use patterns, but, first the aerial photographs & orthophotos and now satellite images have been able to present the actual and exact picture of Land use patterns with very high accuracy.

Examining the change between two time periods has always been the most complicated job for scholars. But the use of computers in the field of Geography as well as in land use studies has contributed a lot to make the job much easier. The development of GIS techniques has tremendously transformed the nature of land use studies in geography (Ghaffar, 1998, 1999; Malik & Ghaffar, 1999). With the use of GIS techniques it has been much easier to map and monitor the land use changes in an area by acquiring the historical as well as latest data from paper maps, aerial photographs and satellite images.

Monitoring Land Use Changes

The development of mankind has completely transformed the human activity in every aspect of life. Agricultural practices, expansion of urban areas, emerging new infrastructure of road, air and railway network, fast growing patterns of industrialization for human needs and use of machines have transformed the patterns of land use on earth. Change in land use patterns in present scenario is an important phenomenon which has very strong effects in present day economic conditions of an area. In order to cop with modern challenges understanding of day to day land use changes is very important. In past, it has been a complicated, technical and time consuming job to map the land use changes (Stamp, 1940s). However, thanks to advancement of science & technology which has made it possible to collect the information regarding physical and human environment from past to present in a shortest span of time. A number of sources such as historical drawings, early topographic maps, aerial photographs and satellite imagery can be used to obtain data about the land uses. Remote sensing and GIS are the most important techniques which have facilitated to map the day to day land use changes.

Use of Remote Sensing

Remote sensing data collected by aero plans, radars and satellites provide efficient methods for collecting and analyzing information about agricultural, urban and various land uses. Since 1960s, satellite remote sensing data is usually the most accurate and up-to-date “map” available for an area. Although, the earliest data available for detecting land use change were on a very low resolution such as 75 km sq. per pixel. Data at this resolution have been used for mapping land cover at continental & global level. Such data have been used to map and monitor land cover & land use change at regional level till 90s. However, very rapid growth in advancement of sensors for satellites and consequently launch of commercial satellites for monitoring human activity has brought very high resolution data for public use at the dawn of 21st century. Spot, Land Sat, Quick Bird and number of other satellites are providing data at a very high resolution as sub-meter resolution at a very low price. The availability of this high resolution data have made it possible to use satellite data for land use studies as well as cadastral mapping in urban areas. Especially with fast growing towns and cities in the developing countries, it is, practically, the only method that can follow up particularly the urban growth (Baudot, 2001). When the satellite image is rectified to a coordinate system, a satellite map can be produced. Together with aerial photography, satellite remote sensing data forms the base for land use mapping and planning.

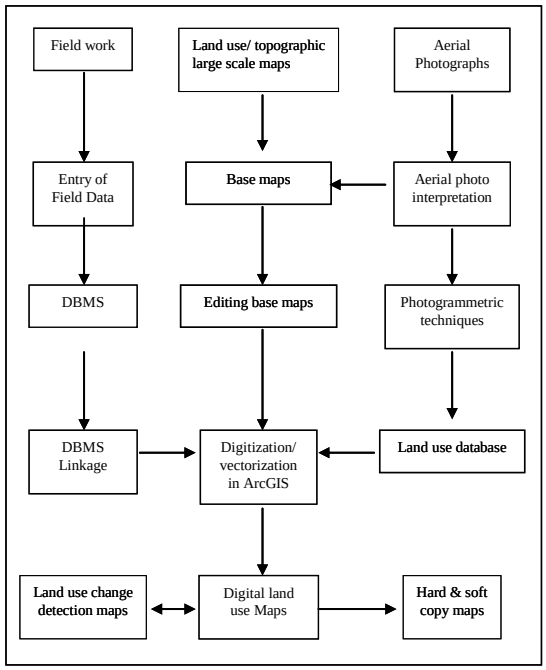

Figure 1: *Land Use Mapping From Aerial Photographs*

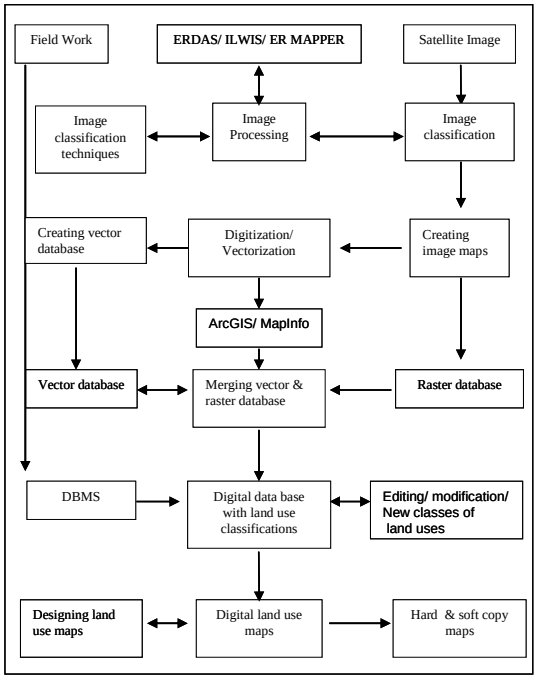

Figure 2: *Land Use Mapping From Satellite Images*

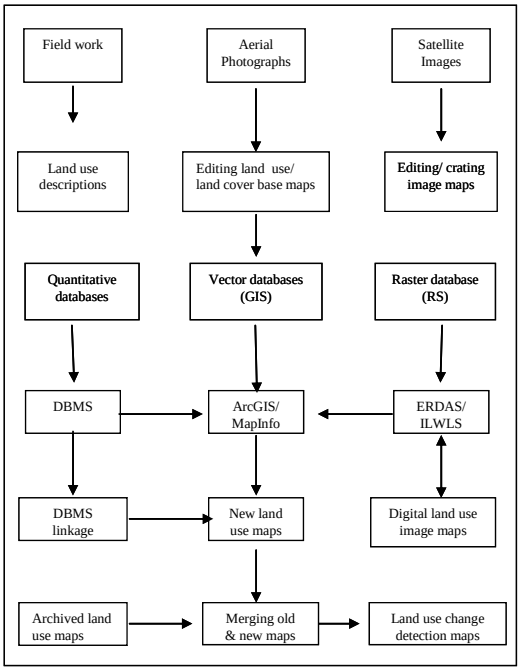

Figure 3: *Monitoring Temporal Land Use Changes*

Although, use of satellite imagery has been very useful for mapping and monitoring land cover in rural areas, however, previously it has been difficult to map urban areas with variability of land cover. In spite of problems of high spatial variability, satellite imagery has been used in urban areas (Harris and Ventura (1995). The resolution of satellite imagery is very important while recognizing the features in urban areas which may hide some of the features due to the poor image resolution. However, a number of authors such as Treitz et al. (1992) and Barnsley and Barr (1996) positively used MSS Tm and SPOT imagery to monitor development activities in rural-urban fringe areas.

To overcome the problems due to poor pixel classification, many researchers (e.g. Pultz and Brown 1987, Peddle and Franklin 1991, have monitor the land use activity based on image texture. A number of image enhancing techniques have been developed to monitor agricultural classification as well as land cover mapping in a mountainous terrain such as Pultz and Brown 1987 examined their utility for an urban environment,

Digital Image Processing techniques are very important while dealing with satellite images. Supervised and unsupervised techniques are available in this regard. However, they have their own merits and demerits. Supervised classifications has proven to be the most effective approach as it evaluates both the variance and the covariance of the category spectral response patterns of each pixel (Lillesand and Kiefer 1994 and Jensen, 1996). The availability of supervised classified image has been very useful for sorting and combining land use classes. These land use classifications can vary from a few to hundreds. Digital image processing softwares like Erdas, Ilwis, ER Mapper and others provide a large number of image processing techniques starting from image enhancement to image classification as well as vectorization of image feature

While monitoring Land use changes in an area it is very important to collect informant about the historic Land use patterns. This job can only be done with the help of archival data. These data is available according to the politico – history of an area. Areas like Europe, Middle East and central, south and for east areas of Asia have very strong politico-history. Large amount of data are available in the form of official, non-official traveler's documents. To some extent historic maps are also available from which past land use pattern can be depicted. However, problem may arise when collecting data about new world. However, depending upon the time, data can be available in the form of maps, Land use maps, documents and text. This data can be transformed to land use maps with some efforts by the skilled labor and technology.

Mapping current land use patterns are much easier job as compare to historic land use pattern. Advancement in aerial photography and satellite remote sensing has made it easy to collect the information and images of most recent or latest patterns of Land use.

Figs 1 &. 2 explain how Land use patterns can be assessed and mapped by various sources and then converted to digital data bases which eventually lead to classify the Land use, their mapping and production of hand and soft copy maps along with statistical summaries. By merging a number of maps belonging to different time periodsLand use change patterns can be detected and monitored.

Use of GIS

The use of computers in Geography in the form of GIS has tremendously changed the nature of analysis of geographical data as well as production, resizing and printing of maps (Mather, 1991, 1993; Taylor, 1991). GIS is very useful for collection, storage, retrieval and analysis of spatial (geographic) data (Masser and Blackmore, 1991). The digital databases are highly valuable because once they are created for any specific area, it is very easy to update these databases (Goodchild and Gopal, 1989; McMaster and Shea, 1991).

The application of GIS in examining the land use changes can probe a number of hidden patterns. The inter-relationship of different land uses such as agricultural, urban, industrial and recreational etc. can only be monitored through the application of GIS. Techniques & equipment and resources available for continuous monitoring of land use change have made it possible to keep an eye on day to day land use changes and making and managing maps of land use of any area. Certainly, it involves the financial and physical resources as well as availability of planners and skill. These resources can only be available through organized efforts such as Govt. agencies and research organization. All efforts starting from infrastructure to data availability, evaluation and management of land uses can be carried for land use maps which can be available for future land use monitoring. The integration and overlay of GIS layers with remotely sensed image data can be very helpful to produce and even create new land use classes. For creation of GIS data layers from paper sources a number of methods such as scanning and digitization are very helpful. However, each method has its own merits & demerits. For instance, scanning can be very useful for converting data from complicated paper maps. Though conversion from raster to vector process is a very skillful job and itself involves time and accuracy and depends upon the accuracy of scale of the source map. Moreover, geo-referencing is the major issue while rectifying the digital database. On the other hand digitization is a time consuming job but it instantly create digital database available for immediate use though some editing may require in new database. However, the problem of map projection, scale of the map and accuracy of the data is addressed before digitization takes place.

Creation of vector digital databases from satellite images is a very important aspect in land use studies. A number of software such as ERDAS, ILWIS and E. R Mapper available which are highly useful for extracting and vectorization of land use classes. Preference should always be given to these softwares since they deal with all issues such as geo-referencing, scale and image accuracy, land use classification and more importantly conversion from raster to vector database. While dealing with vector data preference should always be given to high end software such as ArcInfo/ ArcGIS since it has all capabilities of raster and vector data handling. However, at lower end MapInfo may also be used in small projects where on-screen digitization can be used on satellite images and vector databases can be generated of various land uses classes. Fig. 3 very well explains the nature of procedure to create, manage and monitor temporal land use changes.

Conclusion

This paper contribute a little effort to understand the driving forces of land use development in the past, managing the current situation with modern RS & GIS tools, and modeling the future land use patterns. It also focus the major aspects which are involved in the process of extracting land use information from various sources though a number of ways and monitor and manage these land use changes though RS & GIS Techniques. Remote sensing provides the best data for land use mapping.

With modern geographic information systems, geographical databases can be created pertaining to land use patterns. These databases can be can be very useful for continuous monitoring of land use changes for better use of national resources and to make appropriate policies for economic development.

References

Allan, N. J. R. (1986). Accessibility and altitudinal zonation models of mountains. Mountain Research and Development, 6, 11–18.

Avery, T. E. (1966): *Interpretation of Aerial Photographs*, Burgess, Minneapolis

Barnsley M J & Barr S L (1996) Inferring urban land-use from satellite sensor images using kernel-based spatial reclassification. *Photogrammetric Engineering and Remote Sensing,* 62, 949-58

Baudot, Y., 2001. Geographical analysis of the population of fast-growing cities in the third world in: Donnay, J.-P., M.J. Barnsley & P.A. Longley (eds.), *Remote Sensing and Urban Analysis*, GISDATA 9, Taylor & Francis, London & New York.

Binswanger, H. P., & McIntire, J. (1987). Behavior and material determinants of production relations in land abundant tropical agriculture, *Economic Development and Cultural Change*, 36, 73–99.

Blaikie, P. M. (1971). Spatial organization of agriculture in some north Indian villages: part II. *Transactions of the Institute of British Geographers*, 53 (II), 15–30.

Chisholm, M. (1979). *Rural Settlement and Land Use*. Hutchison, London

Collins, W. G. & El-Beik, G. R. (1971): The acquisition of land use information from aerial photographs of the city of Leeds. *Photogrammetria*, 27, 71-92

Coppock, J. T. (1978). Land Use in Maunder, W. F. (ed) *Reviews of United Kingdom statistical sources* VIII, Pergamon, Oxford.

Datoo, B. A. (1978). Toward a reformulation of Boserup's theory of agricultural change. *Economic Geography*, 54, 135–143.

Downs, C. J. (1991). EC agricultural policy and land use: milk quotas and the need for a new approach. *Land Use Policy*, 8: 206-210

Geertz, C. (1963). *Agricultural involution: the processes of ecological change in Indonesia*, University of California Press, Berkeley,

Ghaffar, A. (1998). Monitoring the Agricultural Landscape: An integrated approach of Maps, Aerial Photographs and Geographic Information System, *Journal Geographic*, 1 (2:), 45-57

Ghaffar, A. (1999): Application of GIS in Landscape Studies: A case study of Berwickshire in South East Scotland, *Journal Geographic*, 2 (2), 1-22

Goodchild & Gopal (1989): *Accuracy of spatial databases*, Taylors and Francis.

Grigg, D. B. (1979). Easter Boserup's theory of agrarian change: a critical review, *Progress in Human Geography*, 3, 64–84.

Harris P M & Ventura S J (1995) The integration of geographic data with remotely sensed imagery to improve classification in an urban area. *Photogrammetric Engineering and Remote Sensing,* 61: 993-8

Harris, R. J, & Longley P. A (2000) New Data and Approaches for Urban Analysis: Modelling Residential Densities, *Transactions in GIS*, 4(3), 217

Harvey, D. W. (1963): Locational change in the Kentish hop industry and the analysis of land use patterns. *Transactions of the Institute of British Geographers*, 33: 123-44.

Harvey, D. W. (1966): Theoretical concepts and the analysis of agricultural land use patterns in agricultural geography. Annals of the Association of American Geographers, 36: 362-74

Ilbery, B. W. (1978): Agricultural decision making: a behavioural perspective. *Progress in Human Geography*, 2; 448-66

Jensen, J.R. 1996. *Introductory Digital Image Processing: A Remote Sensing Perspective*, Prentice Hall

Lillesand, T.M. & Kiefer, R.W., 1994. *Remote Sensing and Image Interpretation*, John Wiley & Sons New York.

Malik, M. K. & Ghaffar, A. (1999-2000): Remote Sensing: A tool for Geographer and Land use planners, *Pakistan Journal of Geography*, xi & x, 1&2: 21-30

Masser, I. & Blackmore, M. (1991): *Handling Geographic Information*, Longman.

Mather, A. S. (1986): Land Use. Longman, London

Mather, P. M. (!991): *Computer Applications in Geography*, John Wiley & Sons.

Mather, P. M. (1993): *Geographical Information Handling - Research and Applications*, John Wiley & Sons.

Mattingley, P. F. (1972): Intensities of agricultural land use near cities: a case study. *Professional Geographer*, 24, 7-10

McMaster, R. B. and Shea, K. S. (ed) (1992): *Generalization in Digital Cartography*, Association of American Geographers.

Muth, R. F. (1961): Economic change and rural-urban land use conversions. *Econometrica*, 29; 1-23

Pultz T J & Brown R J 1987 SAR image classification of agricultural targets using first- and second-order statistics. *Canadian Journal of Remote Sensing*, 13, 85-91

Rhind, D. & Hudson, R. (1980): *Land Use*, Methuen, London

Robinson, G. M. (1991): EC agricultural policy and the environment: Land use implication in the UK. *Land Use Policy*, 8; 95-107

Robinson, G. M. (1993): Beyond MacSharry: The road to CAP reform in Bolsius, E. C. A. et al. (eds), *The Retreat: Rural Land-use and European Agriculture*, The Royal Dutch Geographical Society/ Department of Human Geography, University of Amsterdam.

Ruthenberg, H. (1976). Farming systems in the tropics. Oxford, England: Clarendon Press.

Stamp, L. D. (ed) (1940s): *The Land of Britain: County Reports*, Geographical Publication, London

Symons, L. (1978). Agricultural geography, Bell and Hyman, London

Taylor, D. R. F. (1991): *Geographic Information Systems: The Micro Computer and Modern Cartography*, Pergamon Press.

Treitz, P M, Howarth, P J. & Gong P (1992) *App,lication* of satellite and GIS technologies for land-cover and land-use mapping at the rural-urban fringe: A case study. *Photogrammetric Engineering and Remote Sensing* 58, 439-48

Visser, S. (1980). Technological change and the spatial structure of agriculture. *Economic Geography*, 56, 311–319.