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A Review of Potentialities and Challenges of Integrating Remote Sensing and GIS with Socioeconomic Data

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Abstract – The aim of this paper is to review the potentialities and major methodological challenges of integrating remote sensing (RS) and geographic information system (GIS) with socioeconomic data from published articles or book chapters. RS and GIS combined with social science (SS)(termed as geoinformation technology) serve many applications for sustainable management and monitoring of the environment. This combined approach gives more accurate results than the single one. It makes information available about the trend and pattern of land use and land cover change (LUCC) with socioeconomic variables like population, demographic or income. This combined study which links RS and GIS with socioeconomic data can also be used successfully for monitoring transmission rate of disease and mapping or preparing vulnerability index. For impact assessment and modelling, this combined technology provides better results than the single one. There are some methodological problems for the researchers to link completely two different disciplines as the object of study and observational unit is completely different. However, this interdisciplinary study is gaining popularity day by day to researchers from different disciplines as well as decision makers.

Keywords: GIS, Integration, Land use and land cover change, Remote sensing, Socioeconomic, Geoinformation

Introduction

Remote sensing (RS) is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites. It has been demonstrated as a powerful tool for studying places where it is difficult to reach or difficult to penetrate. RS (aerial photographs or satellite images) broadens the scope of the social scientists to cover phenomena over large areas by providing precise information with a synoptic view from space or from a distance (Taubenböck et al., 2009). Satellite Remote Sensing is an effective tool for natural resources assessment from land to ocean. It provides a timely and complete coverage for land use and land cover change (LUCC) for example, vegetation mapping especially in mangroves where accessibility is difficult (Kamaruzaman, 2008; Kasawani, Kamaruzaman, & Nurun Nadhirah, 2007; Mohd Hasmadi, Pakhriazad, & Kamaruzaman, 2008, Mohd Hasmadi, Pakhriazad, & Norlida, 2011). It is able to provide data in a rapid and cost effective manner and in a non-invasive way, thus gaining popularity in all fields. Satellite Remote Sensing along with Geographic information system (GIS) serves many applications for sustainable management of the environment. GIS technology provides environment to process vast amount of data captured through RS. GIS is able to manage huge amount of data by storing, analysing and representing results in a more simple and attractive way. Different satellite sensors serve to provide information for earth observations at various resolutions. These information depend on the sensors' own characteristics. IKONOS, SPOT (Satellite Pour l'Observation de la terre) and LANDSAT are widely used optical satellite sensors.

In recent days, scientists focus on integration of geospatial tools with other disciplines such as environmental monitoring studies, urban development studies, social science (SS) studies (more specifically socioeconomic studies) etc. for greater detail and clearer understanding of the real situation. Socioeconomic status has been defined as a composite measure of one's resource and prestige in the community where resource include both assets and owning goods of a household and prestige refers to one's status determined by education and profession in a society (Krieger, Williams, & Moss, 1997; Sonya, Brady, & Karen, 2001). Population factors (population size, density or growth rate), household demography such as, household income, age and education level of residents, housing tenure, ethnicity etc. are reported as important socioeconomic variables (Liu, Heilig, Chen, & Heino, 2007; Szantoi, Escobedo, Wagner, Rodriguez, & Smith, 2012; Turner & Meyer 1991; Bagan & Yamagata 2012; Tian, Chen, & Yu, 2013; Gong, Yu, Joesting, & Chen, 2013; Sydenstricker-Neto 2012). The socioeconomic data is generally collected through household survey or census reports. Sydenstricker-Neto (2012) mentioned that household survey is a primary source of quantitative data. Household socioeconomic survey data can supplement to interpret observed patterns of the land cover change by RS or validation (Lambin, Geist, Reynolds, & Mark Stafford-Smith, 2009). Socioeconomic data are strongly related to biophysical environmental data (Bagan & Yamagata, 2012). Thus population and economy are also integrated with remotely sensed data (Xu, Wang, & Xiao, 2000).

Integration of RS and GIS with socioeconomic data refers to conducting a study using tools in combination from RS, GIS and SS for obtaining the goal of the study. There is a relation between socioeconomic variables and the biophysical environment (Bagan & Yamagata, 2012). Many studies reported that human activities are strongly related with land use transformation (Rindfuss & Stern 1998; Anuradha, Reddy, & Paul, 2002; Lambin, Geist, & Lepers, 2003; Small & Cohen, 2004; Doll, Muller, Morley, 2006; Bagan & Yamagata, 2012). For this reason, SS researchers who are studying human dimensions of the global change, have to study about the land use dynamics for better assessment of the real situation. Inversely, the environmentalists or ecologists who are studying about the land use dynamics and causes using RS and GIS tools should study the socioeconomic of the study area as socioeconomic has been reported as one of the major causes of LUCC. Thus the combined study will give more accurate results than the single one. This combined technology can be an effective tool for the socioeconomic study by providing the exact coordinates of the study area or study objects or the land use types. As RS can give information for a vast area or LUCC, it reduces the cost of SS researchers to visit to get to know each and every area of study. Thus it makes the process easier and saves time and money. On the other hand, for different environmental studies, socioeconomic survey data and censuses help to validate the information obtained by the RS and GIS. This combined approach gives more accurate results than the single one. It helps to understand the real situation, to identify the causes, to predict the future situation and to take probable decisions. Thus this technology offers a collaborative research for different disciplines for sustainable management of the environment and society.

The study of integrating of RS and GIS with socioeconomic data falls under the interdisciplinary framework where the pattern and processes of LUCC with socioeconomic data are studied. The integration of household survey and remotely sensed data has been gaining popularity in many interdisciplinary studies as it improves our understanding of the processes along with the causes of LUCC (Herrmann, Sall, & Sy, 2014; Bagan & Yamagata, 2012; Taubenböck et al., 2009; Benoit Mertens, Sunderlin, Ndoye, & Lambin, 2000; Buckle, Mars, & Samle, 2006; Geoghegan et al., 1998; Lambin et al., 1999). This combined study of linking RS and GIS with socioeconomic can be termed as geoinformation technology (Xu et al., 2000). This geoinformation technology is used for various socially useful purposes like population distribution modeling (Sutton, Roberts, Elvidge, & Baugh, 2001), crop forecasting, severe storm predicting, land development planning etc. This technology is also being applied in urban planning or urban development (Xu et al., 2000), monitoring growth of settlements (Thomson & Hardin, 2000), environmental or forest monitoring, information on natural disasters like flooding, earthquake or tsunami etc. This technology has been reported to be most accurate and cost effective providing rapid information for a vast area (Andrade et al., 2010). It can handle vast quantities of spatial and non-spatial data which was previously impossible (Anuradha et al., 2002).

Many studies have been conducted and also being conducted using this interdisciplinary approach (Liverman, Moran, Rindfuss, & Stern, 1998; Moran & Brondizio 1998; Badar et al., 2013; Nazri Che Dom et al., 2013; Nzunda, Munighi, Soka, & Monjare, 2013; Bagan & Yamagata, 2012) although not sufficient (Lambin et al., 2009). Most of these studies concentrated on the African countries (Geist & Lambin, 2002) and developing countries and some of them all over the world. Although linking of RS, GIS and socioeconomic have potentialities and exciting possibilities for studying the people-environment interaction, this technology is not so popular yet due to some major methodological challenges (Codjoe, 2007). These challenges need to be addressed and discussed to make the technology familiar to the researchers from different disciplines. Hence this paper aims to discuss about different studies on the integration of RS and GIS with socioeconomic, potentialities and major methodological challenges. This discussion will improve the understanding on this interdisciplinary study. It also proposes a possible model for integration.

Different Studies on Linking of RS and GIS with Socioeconomic Data

RS along with GIS and SS data can serve many objectives for sustainable management. Xu et al. (2000) termed such interdisciplinary studies as geoinformation technology. To understand the causes, process and impacts of LUCC, this geoinformation technology has been demonstrated as an effective tool. The collaboration between RS specialists and SS scientists will enrich the understanding of the human and environment relation. There are many studies have been conducted all over the world over time by using this interdisciplinary approach. Table 1 presents some interdisciplinary studies combining RS and GIS with socioeconomic listed chronologically from recent to previous.

Table 1: Different studies conducted combining RS and GIS with socioeconomic data

Author(s) and Title of study	Study Area	Remote Sensing data used	Socioeconomic variable used	Major findings/Results
Herrmann et al. (2014). *People and pixels in the Sahel: a study linking coarse-resolution remote sensing observations to land users' perceptions of their changing environment in Senegal.*	Senegal (West Africa)	NDVI	Household food security, health and education status, diversity of income source, no. of rich and poor household	Comparison of perceptions of degradation and greening
Badar et al. (2013). *Integrating biophysical and socioeconomic information for prioritizing watersheds in a Kashmir Himalayan lake: a remote sensing and GIS approach*	India (South Asia)	Landsat TM IRS 1D LISS-III	Total population, total households, literacy rate and economic development status	Integrated impact analysis of socioeconomic and biophysical processes
Nazri Che Dom et al. (2013). *Coupling of remote sensing data and environmental-related parameters for dengue transmission risk assessment in Subang Jaya, Malaysia.*	Malay Sia (South east Asia)	IKONOS satellite data	Population, demographic and housing census data	Dengue transmission risk assessment
Nzunda et al. (2013). *Influence of socio-economic factors on land use and vegetation cover changes in and around Kagoma reserve in Tanzania.*	Tanzani a (East Africa)	Landsat satellite data	Education level, livestock keeping, farm size expansion population growth,	Socioeconomic factors influence Land cover/use change

			agricultural crop prices, land tenure, shifting cultivation	
Bagan and Yamagata (2012). *Landsat analysis of urban growth: How Tokyo became the world's largest megacity during the last 40 years*	Japan (East Asia)	Landsat satellite data	Population census data	Analysis of the trends of LUCC with the population data
Sydenstricker-Neto (2012). *Population and deforestation in the Brazilian Amazon: a mediating perspective and a mixed-method analysis*	Brazil (South America)	Landsat satellite data	Population size, number of adults, household age, year of schooling	Interrelationships between LUCC and human population.
McNally, Uchida, & Gold (2011). The effect of a protected area on the trade-offs between short-run and long-run benefits from mangrove ecosystems	Tanzani a (East Africa)	Landsat satellite data	Income components	Effect of mangrove protection on income components
Andrade et al. (2010). *A socioeconomic and natural vulnerability index for oil spills in an Amazonian harbour: A case study using GIS and remote sensing.*	Brazil (South America)	IKONOS	Income, education level, fishing relationship	Construction of vulnerability index and vulnerability map in GIS
Taubenböck et al. (2009). *Integrating Remote sensing and Social science the correlation of urban morphology with socioeconomic parameters*	Indo nesia(So utheast Asia)	IKONOS	Income per month and value of the property	Correlation of urban morphology with the socioeconomic parameters
Codjoe (2004). Population and land use/cover dynamics in the Volta river basin of Ghana, 1960-2010.	Ghana (West Africa)	Landsat satellite data	Population census data	Assessed the effect of population change on forest cover
Jeremy (2006). *Socioeconomic-Vegetation Relationships in Urban, Residential Land: The Case of Denver, Colorado.*	Colorad o (US)	Landsat satellite data	Population density, household income, educational attainment	Interaction of urban ecological and social systems
Seto & Kaufmann (2003). Modeling the drivers of urban land-use change in the Pearl River delta, China: integrating remote sensing with socioeconomic data.	China (Southe ast Asia)	Landsat satellite data	Socio-economic data	Modelling of rural to urban land conversion
Anuradha et al. (2002). *Application of Remote sensing and GIS in Demographic and Socio-economic analysis of Dehradun city*	India (South Asia)	IKONOS multispectr al imagery	Population density, literacy, sex ratio, child population	Demographic, socio-economic analysis and mapping through RS and GIS
Mertens et al. (2000). *Impact of Macro-economic change on*	Camero on	Landsat and	Population growth,	Deforestation monitoring with

Deforestation in South Cameroon: Integration of Household Survey and Remotely-Sensed Data	(Central Africa)	SPOT satellite data	proportion of migrants, household size, distance to the market	the macroeconomic change
Thomson & Hardin (2000). *Remote sensing/GIS integration to identify potential low-income housing sites*	Thai-land (Southe ast Asia)	Landsat satellite data	Population density,income	Successfully identified potential housing sites with relatively low cost and short time
Xu et al. (2000). *A Remote sensing and GIS Integrated study on Urbanization with its impact on arable lands: Fuqing City, Fujian Province, China.*	China (Southe ast Asia)	Landsat satellite data	Population factors, economic factors	Impact of urbanization on arable land

This combined technology has been used for studying the interrelationships between LUCC and human population, monitoring trend of LUCC with population dynamics, identification of specific socioeconomic factors that influence LUCC, socioeconomic and demographic analysis and mapping through RS and GIS, relationship and interaction of specific land use/cover with socioeconomic parameters, construction of vulnerability index and vulnerability map in GIS, assessment of disease transmission risk, assessment of quality of life for specific land use system, modelling of rural to urban land conversion and impact analysis of socioeconomic and biophysical processes, etc.

Most of the studies integrating socioeconomic data with satellite RS and GIS are conducted by using Landsat data separately or combined with other datasets for LUCC monitoring that support a better understanding of the spatial-temporal change with human activities and contribute for supporting a suitable management practice of the specific ecosystem. Historically Landsat is a popular data set and can cover vast area within a single snap. It is free of cost. Hence it is widely used by the researchers for studying a larger area. The use of IKONOS and SPOT require payment. But they provide better spatial resolution than Landsat. IKONOS is most suitable for studying smaller areas.

The socioeconomic variables that can be studied by this geoinformation technology are distribution of population factors such as total population, population density, population growth rate, number of migrants etc., demographic factors such as age, ethnicity, education level, household size, economic factors such as diversity of income source, monthly income, household assets and value of property, poverty rate, land tenure and quality of life etc.

Anuradha et al. 2002 used IKONOS multispectral imagery for demographic and socioeconomic analysis of Dehradun city in India. Thomson & Hardin (2000) used Landsat Thematic Mapper image with integration to GIS for finding suitable sites for low income housing. They successfully identified potential housing sites with relatively low cost and short time. Xu et al. (2000) integrated socioeconomic data with multi-temporal remotely sensed data for analysing urbanization process of Fuqing City in China. The authors used socioeconomic data for analysing the responsible factors for urban expansion. Mertens et al. (2000) used five (two Landsat and three SPOT) time series satellite data integrated with household survey data for deforestation monitoring with the macroeconomic change in South Cameroon where they concluded that this technology allowed for a better understanding of the drivers of land-use/land-cover change processes of specific region. Andrade et al. (2010) used two IKONOS images along with socioeconomic data for vulnerability studies in an Amazonian harbour where the authors analyzed the physical environment of the area by considering the socioeconomic activities and successfully prepared a vulnerability map of the associated area. Sydenstricker-Neto (2012) used three times (1986, 1994 and 1999) land-cover maps generated from

Landsat imagery with household survey to examine the complex interrelationships between LUCC and human population. Bagan and Yamagata (2012) used Landsat data for 1972, 1987, 2001 and 2011 for analyzing the trends of LUCC and correlated with the population data for those periods. They found a strong negative correlation between the forest or grassland area and the population.

Dom et al. (2013) used IKONOS satellite data coupled with environmental and housing data for dengue transmission risk assessment in Subang Jaya, Malaysia and found a significant correlation of contributing environmental parameters in dengue transmission and distribution pattern. Badar et al. (2013) used socioeconomic data with multi-date and multi-sensor satellite data for prioritizing watersheds in a Kashmir Himalayan lake. The authors prepared a cumulative impact of land use/land cover change, socioeconomic variables and erosion or sediment on the watersheds for prioritization purpose.

Globally, huge work integrating geospatial tools such as RS and GIS with population factors has been conducted but there are relatively few studies on land use changes and their impacts (Nzunda et al., 2013; Strategic Plan for the climatic change Science programme, 2003). Geoinformation technology could provide better results to study the land cover dynamics and its impact to the livelihood of local community for a specific land cover type for example mangroves (intertidal forest ecosystem). By inheritance, Malaysia is rich in mangroves and coastal ecosystems. The population density is increasing to the coastal areas due to urbanisation or other economic developments which can act as drivers to the mangrove change. The study of mangrove change, its causes or impacts to the local community can be conducted by combining RS and GIS with socioeconomic for better results. In Malaysia this type of research is being conducted (Dom et al., 2013) but is still not enough and does not cover all the important areas. So there is a huge scope for conducting this type of interdisciplinary studies in Malaysia.

Major Methodology Challenges for Integration of RS and GIS with Socioeconomic Data

Integration/linking of RS and GIS with socioeconomic extends research for multidisciplinary perspective to analyze and understand any complex systems like biophysical and socioeconomic relationship. For integration of biophysical and socioeconomic data, both fusion of data as well as fusion of two completely different disciplines and scientific traditions is required (Rindfuss & Stern, 1998). Many important things are to be considered for better outcome of the linking process. Socioeconomic is studied under SS discipline. Hence sometimes the term SS might be used instead of socioeconomic to refer to the discipline or for generalization. Being from different disciplines, the SS experts lack knowledge about remote sensing image processing and the RS and GIS experts lack knowledge about social phenomena, theories or methods. Hence there is a huge difference between methodologies of these two fields and linking them is a challenge for researchers in interdisciplinary studies. Several studies have been conducted and discussed in detail about the methodological and practical problems for designing a study of linking household or individuals' information with the remote sensing and GIS (Liverman et al., 1998; Rindfuss, Walsh, Mishra, & Dolcemascolo, 2003; Lambin, 2003; Codjoe, 2007). By reviewing those articles some methodological challenges for linking of RS and GIS with socioeconomic/SS are discussed below:

One of the major challenges for linking RS and GIS with socioeconomic is the heterogeneous data source (Lambin, 2003). Social scientists mainly focus on human oriented social phenomena or abstract variables that explain their appearance and transformation such as government policies, land tenure rules, distribution of wealth and power, market mechanisms and social customs instead of visible human artefacts such as buildings, crop fields, and roads etc. On the other hand in RS, spatial and temporal phenomena are studied such as land use and land cover change, climate change, deforestation etc. Another reason is social scientists are more concerned with why things are happening rather than where they are happening (Codjoe, 2007).

The object of study is different for each discipline. The unit of observation in SS study is individuals, households or communities. The variables of interest for the social scientists are not measured from the air (Codjoe, 2007). On the contrary, for RS and GIS the observational unit is the pixel (picture element- unit of observation), (Rindfuss, Walsh, Mishra, Fox, & Dolcemascolo, 2004) a spatial unit of land which is directly not associated to the SS observational unit and it generally measured from the air or space in the form of reflected bands of the electromagnetic radiations (Mertens et al., 2000).

The data collection method is different. In SS, data collection method is survey and interview with close contact to the study object such as at individual or household level. On the other hand, for RS and GIS studies data collected from satellite images or aerial photography is without close contact to the study object. For the integration process, there are many opinions about the starting point either at the individual level or land level. Rindfuss et al. (2004) mentioned that starting from the land level offers advantages.

The scale of observation is different for the two areas. In RS, studies begin with land first then pixels (Moran, Siqueira, & Brondizio, 2003; Walsh et al., 2003) and in SS, studies begin with household or individual levels (Rindfuss et al., 2003) and later generalised for community or nation to give a broad view of the study subject. If the farm size is smaller than the pixel size then there is a problem with proper geo-referencing (Codjoe, 2007). Appropriate spatial and temporal scale will ensure better linking for SS and RS data and thus ensure better understanding of the causes, process and consequences, as the relationship of land and people is scale dependent (Walsh et al., 1999). So, for linking of RS and GIS with socioeconomic data, the scale of the observation level should be considered and it should be the same level for both types of data. The scale or the level of observation is mainly determined by the objectives or the research questions of the specific study and availability of data (Lambin, 2003). For the linking study, the scale of observation also depends on the spatial resolution of the remote sensing data. Otherwise it would be difficult to give a clear understanding of the study unit. For example, IKONOS provides better spatial resolution than Landsat. Hence the integration study at household level or smaller area with IKONOS data will be more accurate than Landsat. On the contrary, for study of a larger area, like at the national level, Landsat will be more suitable as it can cover vast area within a single snap.

For identification of causes or factors of any LUCC, linking of smaller area will be better to refer to actual factors. But for larger area, when linking with socioeconomic factors, some of the factors may be merged with others for generalization of data. Hence, linking household level socioeconomic data with RS and GIS is logical as the land owners or household heads generally decide how they will use their land parcels and the decision reflects their socioeconomic conditions. If finer scale observation is the objective of the study then household level linking of RS and GIS with socioeconomic data will be considered. It will help to assess the real cause of the land use change, although there are still some problems that occur for linking at individual or household level. Higher spatial resolution RS imagery such as IKONOS is needed for clearly geo-referencing the heterogeneous, small households. Logistical sufficiency should also be under consideration (Lambin, 2003) as every plot of household has to be geo-referenced. Moreover, if the farm size is smaller than the pixel size, it is difficult to link at household levels. Additionally, linking household level is costly, time consuming and labour intensive as geo-referencing for all the interviewed households should be done. The interviewers have to travel to every plot or household to collect the GPS coordinates. Otherwise the study will not be justified. If the sample size is large then it will be more difficult. Rindfuss et al. (2002) proposed a smaller sample size for such study can reduce the time constrains.

The village level linking is easier than household level linking. Only the village boundaries need geo-referenced although the data to be collected is at household level and later aggregated. But there is a problem of data masking. Because at village level linking the relationship of variables may mask and information may be lost due to aggregation of land-cover change data to a coarse resolution (Wood & Skole, 1998; Lambin, 2003). As it considers the average values for the household data instead of the heterogeneity between the factors.

A time series data is needed for better linking RS and GIS data with socioeconomic survey data. For RS and GIS, time series data is available but for household survey sometimes it is not available or not possible to collect data over time (Verburg, Chen, Soepboer, & Veldkamp, 2000). If the study is doing with longitudinal survey approach and time series RS and GIS data collected within the timeframe of the survey period then it may be possible to link socioeconomic with RS and GIS. But this approach is expensive and time consuming and sometimes impossible. Generally the survey approach 'cross sectional survey' is popular to the researchers. Linking with cross sectional survey becomes difficult for lack of data. In this case, census data can be used to supplement the previous years that are not surveyed, although there may be another problem with the scale of observation, as the census report is always in aggregated form for the smallest administrative level. For example at Mukim level which is larger than village level. Another problem is census reports can provide some specific socioeconomic indicators and researchers have to adjust with this reports sometimes by reducing the number of socioeconomic variables. Important variables may be ignored from the specific research objectives.

Lack of experience is another challenge for accurately overlaying the pixels from various images with same land units of household or a person. Sometimes the landowners live far away from their land. Sometimes they live in nucleated villages those are far away from their fields. Then there is a problem with linking population with the land use for population dynamics and land cover change study (Lambin, 2003; Entwisle, Walsh, Rindfuss, & Chamratrithirong, 1998). Codjoe (2007) included some other problems for properly linking are, cloud cover on the image and classification error during image processing. Although there are some methodological challenges for integration of the two completely different disciplines it can be overcome by proper training and by planning a combine study where researchers from both fields will work together and by adopting a proper methodology. Scientists all over the world are more concerning about the integration of these two disciplines as there is a huge opportunity of this combine study.

Discussion a possible Model for linking of RS and GIS with socioeconomic data

Many studies have been performed for linking RS observations and socioeconomic data in different regions of the world and many of them are conducted in Africa (Entwisle et al., 1998; Rindfuss et al., 1996; Mertens et al., 2000; Guyer & Lambin, 1993; Geist & Lambin, 2002). These studies were conducted in different scales such as, global, regional, and local. In most of the local studies, scale chosen for linking at the administrative unit level such as village or county levels, etc. (Green and Sussman, 1990; Skole, Chomentwoski, Salas, & Nobre, 1994; Geoghegan et al., 2001). The advantage for choosing village level data linking with socioeconomic data is the village profile data will be used for cross check or to validate the dynamics observed by the RS results (Entwistle et al., 1998; Mertens et al., 2000). Additionally it would be cost effective requiring less labour than linking household level, although the household survey data gives detailed information not available to the village profile and makes the real situation about the subject of study easily understandable. After data collection, household level data would be aggregated to the administrative unit level for instance village level with the same scale of RS data for linking properly. Geo-referencing is necessary for only the land use boundaries at village level rather than every plot in households. Lambin (2003) proposed two ways to define the land use boundaries at village level. One is by assuming a maximum travel distance to the plots from houses and the other is by identifying the land use boundary of a land use on a map with the help of a key informant (village chief). Thus in order to link social, natural and spatial data household level, survey data would be aggregated to the village level, and can easily be linked with the RS and GIS data for the same boundary. Then a village level attribute table will be prepared and overlaid in GIS. The scale of observation should be chosen based on the research questions and availability of data. If finer scale observation is the objective of the study then household level linking of RS and GIS with socioeconomic data will be considered.

There are many models that have been developed and used for linking RS and GIS with SS in different studies. The usability of these models depend on the perspective on which it be applied. Lambin (2004) reported that land use change models are able to answer the questions – (i) Why? (ii) Where? and (iii) When? Here (i) Why refers to which associated factors or variables are responsible for the change. (ii) Where refers to the location that is affected by the change i.e. the hotspot of the change and (iii) When refers to at what rate the change occurs. Models help to understand the land use dynamics. In land change studies, models are used to understand the present scenario of change with associated drivers and to predict the future scenario (Brown, Page, Riolo, & Rand, 2004). The model output helps the decision makers for proper planning for a sustainable development.

For integration of land use change with socioeconomic study the CLUE-s (Conversion of Land Use and its Effect at small regional extent) can be proposed to be adapted. CLUE-s is the modified version of the most widely used CLUE (Conversion of Land Use and its Effects) model. The CLUE model was developed for regional scale land use change studies for different studies like agricultural intensification, deforestation, land abandonment and urbanisation etc. (Verburg & Overmars, 2007).

CLUE-s is a spatially explicit model; here the unit of analysis is an area of land, either a polygon representing a field or plot, or a pixel. It is a multi-scale, hybrid model that is developed for understanding the drivers of land use change both present and future. This model is based on high resolution data where each pixel contains only one land use type and spatial resolution ranging from 20 to 1000 metres (Verburg et al., 2002; Verburg & Veldkamp, 2004; Overmars, Verburg, & Veldkamp 2007). CLUE-s model consists of two parts: (i) non spatial demand analysis part and (ii) spatial analysis part.

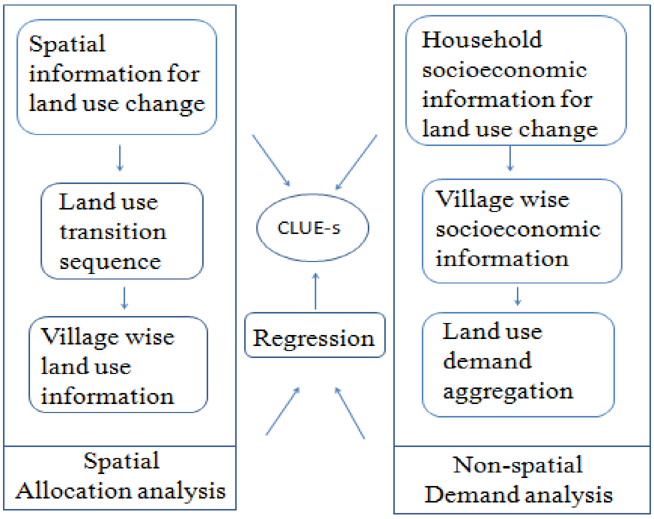

Figure 1: Overview of information flow in the CLUE-s model
Source: Adapted from Verburg and Veldkamp (2004)

Conclusion

Integration of RS and GIS with socioeconomic data can be termed as geoinformation technology. This technology makes collaboration between researchers from different disciplines and can be used by a large group of researchers from different disciplines like ecologists, economists, social scientists, environmentalists and decision makers. This technology is reported an effective tool for sustainable management of the environment as the biophysical environment and socioeconomic variables are strongly related. For LUCC monitoring it provides better understanding of the process and pattern with associated socioeconomic causes; hence this technology is gaining popularity. It is cost effective and provides better results than any of those single studies. However, some methodological challenges have been reported when combining two completely different disciplines. Heterogeneous data sources, study object, unit of observation, data collection method, observation scale, etc. are mentioned. Scientists all over the world are more concerned about the integration of these two disciplines as there is a huge opportunity in the combination.

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