InSight Bulletin: A Multidisciplinary Interlink International Research Journal
Peer Reviewed International, Open Access Journal.
ISSN : 3065-7857 / Website: https://ibrj.us / Volume-2, Issue-5 / May - 2025

Original Article

Spatial Analysis of Agricultural Land Use Patterns: A Geographical Perspective

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Manuscript ID:
IBMIIRJ -2025-020501

Submitted: 02 Apr 2025

Revised: 16 Apr 2025

Accepted: 03 May 2025

Published: 31 May 2025

ISSN: 3065-7857

Volume-2

Issue-5

Pp. 1-8

May 2025

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OPEN ACCESS

Quick Response Code:

Web. https://ibrj.us

DOI: 10.5281/zenodo.16632017

DOI Link:
https://doi.org/10.5281/zenodo.16632017

Abstract

This study explores the spatial and temporal dimensions of agricultural land use patterns through a geographical lens, emphasizing the integration of GIS and remote sensing technologies. It distinguishes between static and dynamic analyses to assess the spatial distribution and temporal transformation of agricultural practices, particularly in metropolitan regions. By incorporating farmers' behavioral insights, environmental variables, and policy impacts, the paper evaluates land use changes across diverse case studies from Sudan, Bahrain, and the U.S. Midwest. The findings underscore the role of topography, soil fertility, and climate in shaping agricultural patterns, and highlight the implications of urbanization, policy interventions, and sustainable practices. The research contributes to a deeper understanding of agricultural land use dynamics and offers directions for future research leveraging emerging geospatial technologies.

Keywords: *Agricultural Land Use, Spatial Analysis, Land Use Change, Urbanization, Sustainable Agriculture, Land Use Policy, Temporal Analysis, Soil Fertility, Cropping Patterns*

Introduction

Land use change has been a main topic of interest among geographers as it directly represents the human-environment relationship. Due to the alteration of land use by human activity, the development state and also the nature of earth environment are changing dynamically. Agricultural land use, which is originally a main topic of interest, has been analyzed from both temporal and spatial aspects. The research about temporal change of agricultural land use fell into two categories according to their perspectives; one is a study on the selection and competition on agricultural land use through modeling which takes a macro viewpoint of farmers' behavior, and the other is a research considering the actual conversion of agricultural land use witnessing on the agricultural landscape through intensive field survey on each farmers' behavior. Research on the spatial analysis of agricultural land use focused mainly on the newly developed cities of developing countries to find the characteristics of agricultural land use in the temporary circumstance and infer its implications on the sustainable urban development, there are two main perspectives on this kind of research; one is a static analysis of actual agricultural land use to identify its spatial distribution and patterns, while the other is a dynamic analysis of temporal variation of agricultural land use from past to present to reveal the driving forces of the change. To analyze the temporal aspect, the data of past state was needed, however, given the difficulty of information gathering, few studies have been done on this method.

Theoretical Frameworks in Spatial Analysis

As a simple definition, "spatial analysis" comprehensively indicates methods that focus on the topological relationships inherent in spatial entities. Such a definition embraces a wide variety of methods from a broad range of disciplines including, but not limited to, geography, geology, mathematics, cartography, forestry, hydrology, meteorology, and even anthropology (Toshio & Eranga, 2015). So-called GIS (geographic information system) is a nomenclature not only favored in academia but even in nowadays mainstream society to refer to a tool that coves several facilities for spatial analysis. As commonly accepted, GIS commonly stands for computer-controlled systems which capture, store, check, analyze, interpret, and display a wide range of spatial data to assess reality (usually designated as the ABC of GIS). However, it may not be encroachingly conceived like so.

How to cite this article:
Moharkar, R. J. (2025). Spatial Analysis of Agricultural Land Use Patterns: A Geographical Perspective. Insight Bulletin: A Multidisciplinary Interlink International Research Journal, 2(5), 1–8. https://doi.org/10.5281/zenodo.16632017

The concept of GIS could be as simple and fundamental as methods performed in a dimension into which a space is plotted, although procedures could be complicated (Duro, 2012).It is also common to refer to either conventional or more advanced method used in GIS as spatial analysis. Such a diverse acceptance of the term sometimes causes confusion and inconsistency. At this point, it is worth defining what are intended on "spatial analysis" in a narrowed manner that is limited to geographical perspective.

Methodology

The analysis of agricultural land use changes in metropolitan areas is widely recognized as an important research topic in geographical studies, bringing together efforts by many academic disciplines (Toshio & Eranga, 2015). This is largely because agricultural land use is an environmentally and economically important land use category; thus, its spatial distribution has historically attracted the interest of geographers. Questions such as where a particular type of land use is located have often been posed in this category of research. Studies of agricultural land use typically focus on the static aspects of land use; thus, consideration of the temporal changes in agricultural land use is not commonly made. However, this time dimension is considered important to understand the dynamicity of agricultural land use. Recipients of such research results include not only the scientific community but also related governmental organizations. Owing to numerous on-line databases, it is now possible to collect land price, meteorological, market, farm, and government data to build a database for a selected metropolitan area. These factors influence the decision-making of farmers in adopting certain agricultural technologies. It is equally important to undertake behavioral studies of farmers concerning their land use decision making in these on-line websites. Another interesting research subject is to consider the applicability of conducted agrosystem alterations to other metropolitan areas (Duro, 2012). Approaches used in other geographic areas, crops, land use systems, or different farm sizes may be used to enhance the reliability and transferability of research results. Counter-arguments, such as credit and market relations, soil and water limitations, and farm cultures, should also be considered. Since agricultural land use is intimately connected to urbanization and regional development, the research perspectives should be expanded to consider these broader issues. The analysis of agricultural land use changes in metropolitan areas is widely recognized as an important research topic in geographical studies, bringing together efforts by many academic disciplines. This is largely because agricultural land use is an environmentally and economically important land use category; thus, its spatial distribution has historically attracted the interest of geographers. Questions such as where a particular type of land use is located have often been posed in this category of research. Studies of agricultural land use typically focus on the static aspects of land use; thus, consideration of the temporal changes in agricultural land use is not commonly made. However, this time dimension is considered important to understand the dynamicity of agricultural land use. Recipients of such research results include not only the scientific community but also related governmental organizations.

Data Collection Techniques

Given the indicators of forest change, freely available remote sensing datasets which provide global forest cover maps for different years were evaluated to construct a time series of forest change maps on case study level. The selected datasets were mainly based on OLI with improved cloud-filtering algorithms and multi-resolution conception to cover differing climate zones, differences in annual observation time or partitioning of regions required for processing (Duro, 2012). GlobCover 2005 was used for the classification of land cover classes. For the current land cover and for the vegetation change rates, the most recent dataset available in the World Agri-Climate and Soil Resources database (year 2005) was used.

A geographic information systems (GIS) was employed to geographically analyze such datasets. It is essential for the measurement of spatial phenomena for understanding how phenomena are distributed in space, over time, and how they relate to other phenomena. GIS are computer-based systems for development, storage, management, validation and analysis of spatially referenced data. They bring together capabilities of digital cartography, computer-aided design, and database management systems which enables the representation of spatial location in either graphical or numerical forms and the linking with descriptive characteristics in data tabular form. GIS is a tool to question What. What phenomena do we have? Where are they? To whom do they affect? What is the spatial pattern? These questions initiate geographic analysis which is fundamental for further gain of understanding how phenomena interact and how they change over time. They inquire the spatial nature of phenomena in terms of location, organization, unfolding of hierarchy, direct and indirect interactions and social or economic impacts.

Geographical Factors Influencing Land Use

Land use pattern is the outcome of the parameters and processes that act on the land surface to create a region that functions as a proper whole and is internally consistent (Toshio & Eranga, 2015). The use of land is practiced at different spatial and temporal scales, with the management of a piece of land being influenced by its local conditions and social organization, and also by the ones further away. In the new millennium, land use patterns are increasingly of concern due to the global population growth and economic development, which put more strain on the agricultural land. Hence, agricultural change has focused on changes in land and its use practices within a landscape (spatial transformation) over time (temporal transformation). Understanding spatial and temporal changes in agricultural land use is essential for sustainable agricultural land use, as excessive change affects ecosystems, biodiversity, greenhouse gas emissions, and hence human well-being. Agricultural land use is the use of a plot or area of land as conducted by farmers. Often it implies how land is divided into agricultural households by land tenure. Land is used for agriculture which is generally not used for any other activity in several areas, while in other areas land may be divided into different tenures with each tenured section being used for agriculture. Land use changes and their effects grow with agricultural expansion, increased population, and changing agronomic practices. Land use change (LUC) is a permanent change in land use or land cover from one type to another. They can either be natural or anthropogenic. Natural LUC occurs without human intervention for changes like storms, floods, and fire, while anthropogenic LUC is caused by human activities as a result of demand/supply changes resulting in agricultural expansion or overgrazing leading to desertification. Possible land use types include cultivated, grazing, bare, and forest land, with LUC being a change in coverage/usage from one to another.

1. Climate and Weather Patterns

Climate is the most prominent and influential physical factor in agriculture, since it possesses a significant impact on the possibility of growing food crops. Weather patterns are manifestations of climate. Climate varies according to the latitude and topography, while weather patterns are characterized by the operation of air masses, the phase of circulation by winds at different levels, precipitation distribution, moisture and temperature variations.

Climate is varied by two systems: the Koppen classification system, which deals with temperature and moisture, and the Thornthwaite classification system, which deals with potential evapotranspiration. The systems are denoted by universally accepted letters and subscripts, each of which stands for a certain condition of climate. Eight systems, which are lettered A through H are accepted over the world (Zabel et al., 2014).

2. Soil Types and Fertility

It has usually been recognized that the land has an important influence and part to play in determining agricultural production. This is understandable in a country like England where so much of the country is in agricultural use. However, the general acceptability of this viewpoint is in spite of the fact that the scripts in the first two chapters show that much of the actual agricultural land use is very poor indeed and exerts little influence on production. In an efficient and competitive agricultural system land may be used unsuitably resulting in low marginal return or even losses. Agricultural land use can be a fit object for that analysis which in less agricultural, developed and developed countries satisfies either criterion of significance or interest, and the tools of spatial analysis can be applied to it (Doka, 1983). Besides the influence of the land and understanding agricultural land use the latter, especially making the understanding spatially expressed, can contribute to the understanding agricultural production. It is hoped that a better understanding of the spatial variations in the forces which shape agricultural land use can lead to improved agricultural land use policy making. The aim of the research is to discover extent and spatial pattern of agricultural land use, and reconstruct land use types of two subsequent years in order to understand the dynamics in agricultural land use. The first step is to measure agricultural land use (types) at different spatial levels of resolution. Classification of land use and data availability makes it difficult to standardize definitions and hence compared unravel or misunderstood results considerable effort is made to elaborate on comparative data defining, estimation and classification of agricultural land use (types) in part one. After understanding agricultural land use (types) the forces which shape agricultural land use are analysed. A wide variety of forces shape agricultural land use. It is tried to disentangle and systematically order them in order to improve adequate agricultural land use policy making.

3. Topography and Landform

Elevation is the vertical distance of a location in relation to sea level and elevation data are presented as Digital Elevation Models (DEMs). Digital Terrain Model (DTMs) stores both the elevation values and the feature identifying values (e.g., slope, curvature). Terrain analysis involves the calculation, analysis, and visualization of basic landscape parameters derived from DEMs/DTMs (Metternicht et al., 2005). Topography includes all landscape features that include the relative height, slope, and curvature of the land. A topographic analysis consists of calculating and interpreting georeference scalar values describing the landform characteristics such as aspects, curvatures, slope, and view shed analysis. Topographic attributes derived from the DEM models are used for landform and landform parameter classification. The nomenclature for the classification combines level (class group) and the shape and/or specific process acting on it. Topographic attributes of land surface which characterize the irregularity and complexity of the land surface play a significant role in hydrology, geology, geomorphology, ecology, and so on. This paper presents a generalized classification of landforms in Vietnam. This study also examines local morphological properties of the land surface terrain based on the DEM and generates a refined topographic map to reflect the terrain characteristics. The study applies deep learning random walk algorithm to classify and extract river networks within Vietnam; this study will be useful for various problems such as hydrology and land use/vegetation change simulations on earth.

Case Studies

Land use changes in agricultural environments are discussed qualitatively by using Landsat ETM+ data with a temporal magnitude of 10 years (Duro, 2012). Land use changes are depicted on principle land use maps, which describe general land use patterns. With the growing availability of satellite imagery, computational capacity, and extensive land use databases, reliable data are available to enable a quantitative analysis of land cover change. Remote sensing is used to provide quantitative methods for the extraction of 11 land cover classes based on five multi-spectral bands of Landsat ETM+ imagery and an annual land cover map is generated for the years 2000 to 2010 which describes land cover changes on a quantitative basis. Agricultural land use is analyzed based on agricultural land use intensity information derived from normalized difference vegetation index time series data extracted from MODIS products. Early cropland mapping is undertaken followed by the spatial disaggregation of census-based agricultural land use group information.

The direct analysis of spatial patterns and detecting the location and direction of their change over time are a potential tool in land use studies. This interest is fueled by advocacy for careful or sustainable land use, which is more easily expressed in the spatial domain. This paper illustrates an approach combining geographic information systems and remote sensing techniques to describe, understand, and model spatial patterns of cropping intensity in an agricultural environment in eastern Hupeh, China. Using 3960 250m resolution NDVI time series images between 1998 and 2005, three satellite-derived continuous variables, cropping intensity, cropping diversity and crop cover fraction, are produced to characterize spatial patterns of cropping.

1. Case Study 1: Region A

Region A is one of the nine Regions in which Sudan has been divided politically, administratively and geographically. It consists of the two randomly selected districts, namely Berber and Abu Hadriah. The total area of this Region is one hundred seventy two thousand eight hundred fifty-one square kilometers. The Berber district lies to the north of the Nile, between latitudes 16°30´N and 17°15´N, and longitudes 33°15´E and 34°07´E. Abu Hadriah district lies to the south of the Nile, between latitudes 16°34´N and 17°25´N, and longitudes 33°22´E and 34°07´E. Sudan lies within the tropical belt. Most of its territory is covered by hot arid desert, known in Arabic as Gzar. The distribution of rainfall therefore varies accordingly, resulting in different situations regarding availability of water for plant growth. The rainfall, which has a great imperfection in delimiting height, varies from the dry desert of less than 50 mm annually in the north to the wet tropics of over 3500 mm in the south. Most of the area lies in the semi-arid belt where conditions are favorable to plant growth. Rainfall in this belt ranges, and the duration of the rainy season varies. Wetness, dryness and heat stress are the primary factors which support or restrain the agricultural land use in this age of increasing population. The Nile is the only perennial river in the country, but few are dependent on irrigation, mainly because irrigable soil is not widespread and because, even where available, construction costs are prohibitive.

The relatively adequate rainfall of a narrow belt of country along the border of equatorial Africa, is not fully utilized. Though some of this annual variability could be predicted, the assessment of the moisture availability for agriculture before planting by means of forecasting is of great importance. The weather stations are insufficient both quantitatively and qualitatively, and the meteorological evaluation, which should be carried out by experts, is not done in the Region. In order to help in farming activities both to avoid wasteful planting and to utilize the full development of the growing season, the evaluation of the agricultural potential for various regions in the Sudan is warranted (Doka, 1983).

2. Case Study 2: Region B

Bahrain, an Arab island nation in the Middle East, presents a unique case for understanding the dynamics of agricultural land usage in a small, oil-rich country. The State of Bahrain has a population of 1.32 million people, of which approximately 508,000 are foreign workers. This makes a density of 1,098 person/km². Although the 2001 census showed a population increase of 89,477 over a decade, the country's total area declined due to land reclamation. Agricultural lands are mainly limited to some 12.5% of the land area, while the remaining area is devoted to buildings and roads, or is barren sandy soil. The best agricultural land is located in the northern and western parts of the Island. The so-called 'traditional agriculture' represents 5% of the country's agricultural area, in which a variety of horticultural crops are cultivated using sophisticated irrigation systems. Most of it is dedicated to vegetables and fruits, and only limited crops are being newly introduced or adopted. Emphasis is directed towards development of high-value crops suited to greenhouse or hydroponic cultivation, controlling the outer climate zone with suspended shading and ventilation or water retentive caps.

Non-traditional agriculture is characterized by soil-less culture of mass produced ornamental plants, flowers, and vegetables in multi-span greenhouses, or by hydroponic fertilized cultivation in high-tech plastic houses. Greenhouses, tents or canopies account for a significant portion of the total agricultural area, with about 1,300,000 m² structures. In the absence of precipitation, organised irrigation systems supply warm water, which is reused. In farm units, the fertilized hot drain water entails the risk of virus diseases to other mass produced crops. Recently, there has been a confirmed paradigm shift towards the so-called Nutrition Programs, freely encouraging soil-less culture of high-value crops to areas with high Landfilling Potential.

Spatial Patterns of Agricultural Land Use

1. Land Use Classification

In this study, the land use types are first classified and described. By combining the classification with other information the overall changes in the agricultural land use patterns are investigated. The land use classification system is derived from the CORINE land cover classification system. The CORINE land cover was developed for the monitoring of the European environment to evaluate. However broad range local studies have also been implemented including agricultural studies. The CORINE land cover classification map has been used in many parts of the world outside the continent of Europe (Denton & Ogunkunle, 2014). The CORINE land cover distinguishes 44 detailed classes grouped by 4 large classes. A more simplified version with 26 classes is used intensively in region based studies. The CORINE land cover classification has one more statute, the database and/or maps with CORINE land cover classification on a scale 1:100.000 is compiled for the whole Europe. However for many parts of the world CORINE land cover base maps need to be produced again. For some regions the classification is adjusted to local conditions complemented with local detailed classes. A system classification hierarchy is developed for this study according to the CORINE classification. The major classes suitable for the regions of sub humid and humid savannas are developed in a smaller class. The hierarchy system generated for this study contains a main type (level 0) and a choice list. At level 0 the land use types broad classified into four classes, namely cultivated area, forested area, built-up area and others. The second level includes the detail classifications of the four broad groups, however in the case of “others” there is no detailed information. The system classification listings as well as the land use types are completely validated by the land use experts in the study country (Duro, 2012). The classified image is treated as the reference data and is titled “reference”.

2. Spatial Distribution Analysis

Spatial distribution analysis is an important theme to determine land use recognizing its static aspect by providing the spatial pattern of agricultural land by quantitative data. The analysis mainly focuses on identifying the spatial pattern of land use which is usually measured by the evenness of the spatial distribution of land use. Land use in a geographical area is limited and categorized into various classes such as agriculture, finite resources, and other types of land use. Each class of land use is, usually, defined by certain type of activities and its outputs. On the other hand, an analysis of land use recognizes two main components; areal extent showing the size of a given type of land use and spatial distribution showing the pattern of distribution of land use.

Identifying the spatial pattern of land use is important in understanding the land use structure. The spatial pattern of agricultural land use, which is the main topic of this thesis, has been a main research theme among geographers, which is concerned with determining the spatial arrangement of agricultural land use. By observing this arrangement, land use with a wide variety in location and characteristics is simply categorized. Moreover, as land use is determined based on people's life style and actions, the spatial pattern of land use change is believed to reflect the socio-economic structure in a community. This information would be useful particularly in formulating agricultural policies to secure food safety and other relevant regulations. On the other side, as land use is limited in size, spatial patterns the distribution of agricultural land use change over time. On this point of view, quantifying the spatial patterns of land use change typically provides insights about the way in which these spatial patterns emerge showing how the agricultural land shapes and arrange. The spatial pattern of agricultural land use change, therefore, is determined by understanding its static aspect by providing the spatial pattern of agricultural land use by quantitative data (Toshio & Eranga, 2015).

Two main aspects of the spatial pattern of agricultural land use are recognized. First, spatial patterns can be expressed by the concentration of agricultural land deducing the shape of a land. Applying this concept to agriculture, agricultural land is the areas growing vegetation for food and other outputs, which is, usually, limit in the number. The cropping pattern thus indicates how each agricultural land is arranged in a geographical space. In statistical terms, it is referred to as spatial distribution. It is denoted by the sets of objects or events and their locations in space and can be described by identifying the evenness of the spatial distribution of a population. Quantifying the spatial pattern has been recommended mainly by three types of analysis; Description analysis is basically expressing the spatial pattern by illustrative maps. The first approach typically illustrates the spatial pattern of farming land by basic maps showing each attribute separately (Cheng et al., 2015).

3. Temporal Changes in Land Use

Understanding the temporal changes of land use is of great importance for agricultural land use research. First, the direction of land use changes often differs between the past and the future. Thus, for any studied region where agricultural land use pattern is expected to be similar or changed in a certain direction in the future, knowledge of the past agricultural land use patterns is indispensable in the form of historic land use maps. Second, many causes of land use changes, including urbanization, population growth, elevation of GDP, and agricultural technology innovations, may take a period to impose their effects on a studied region (Toshio & Eranga, 2015). Thus, to know in what period a certain factor became influential in inducing land use changes helps to better understand the process of land use changes.

However, rigorous and systematic studies on the past agricultural land use changes have not been adequately published in Northern China at a detailed spatial and temporal resolution. Most published studies in this region are focused merely on the spatial distributions of agricultural lands at a single time point. There are some studies of agricultural land use changes in the Beijing metropolitan area and the Pearl River Delta region, but without historical data restoration. A few studies have reconstructed past land use maps, but have focused on forest land use and merely one time point.

Impact of Agricultural Practices

1. Sustainable Practices and Their Effects

Sustainable agricultural practices, development priorities, and changes in agricultural land use policies can all affect agricultural land use intensity. Similar changes in agricultural land use intensity can occur in different farm zones that encompass significantly different geographic areas. Understanding the potential effects of these agricultural policies and developments would be useful information for land use planners, since widespread changes in agricultural land use intensity would have significant environmental and economic repercussions across a multi-jurisdictional area. Remote sensing and models were used to provide a consistent and objective understanding of agricultural practice. Comparisons of results from different sources can help assess the relative differences in applicability of different approaches to understanding patterns of agricultural land use. An area in southeast Queensland spanning several local government jurisdictions and characterized by intensifying agricultural land use resulting in socio-economic and environmental concerns was chosen as the focus of study. An optimization-based approach to provide a spatially explicit representation of agricultural land use that could be interpreted in terms of land use intensity and informed of changes in that intensity was developed. The spatial output of a choosing among alternative agricultural land use model based on systems of linear equations was derived and spatial weights, indices, and change matrices were derived to provide spatially explicit measures of agricultural land use intensity compatible with agricultural census data.

Information on key components, drivers, and changes affecting local performance as indicators of agricultural land use intensification is needed to help identify what adaptations might be necessary to mitigate the adverse consequences of intensifying land use. Much of the agricultural land use evaluation in the past has taken a comprehensive area-wide view of agricultural performance using region or sub-region wide aggregated data (Duro, 2012). The significance of spatially dispersed changes in agriculture at local levels, impacts of which are often very different from overall trends, was often underappreciated. Land use intensity patterns, such as drought spots or hot spots of vegetation clearing, have proven invaluable for a cost-effective identification of the most significant areas to target for increase of local agricultural land use quality. Such analyses could provide an important preliminary step for targeted surveys and more comprehensive assessments of influencing factors to potentially inform change mitigation mechanisms.

2. Economic Implications of Land Use

There are instrumental functions of land use data projected within the social sciences perspective, and correspondingly an economic lens to highlight implications of land use change and preservation to certain land uses. In this economic critique of agricultural land use change, economic implications of urbanization, and concerns about embedding that in policy recommendations to preserve a certain pattern of land use are presented. Urbanization is an important mode of economic development. Urbanization enables a more efficient division of labor, and the emergence of complementary industries takes advantage of external economies of scale. Urbanization generates increased productivity due to rising knowledge spillovers, and this is reinforced through the clustering of creative industries. Land use transition from agriculture to urban may be understood through an economic lens on how these attributes of urbanization contribute to economic growth. As well as losses to agriculture, there are gains to urbanization, and its persistence suggests a net growth in productivity. Agricultural land as valued functions services may be better incorporated into studies of changes to land use due to urbanization. Urbanization may also be an influential agent of perilous change to land use patterns. Land use change to urban may spawn a removal of high-value farmland, and associated agroecosystems, with associated loss of ecosystem services provided by agriculture to health, landscapes, climatology, scenery and familiarity. While urban development may address issues of economy, thriving simply at the highest land price points may displace access to certain resources, degrading essential functions of geography to provisions and liveability. Conserving agricultural land is concerned with protecting the functions and benefits provided by this land (Perry, 2019). There are arguments to shape policy recommendations consistent with publicly accessible research on spatial distributions of land uses for this concern.

3. Environmental Consequences

Land degradation, soil erosion, pollution, loss of biodiversity, and desertification are among the serious concerns of environmentalists. Agriculture is an important landmark for soil erosion, loss of nutrients, and environmental pollution. Excess fertilizer application to cropland causes agrarian runoff pollution. Pollution due to eutrophication is caused by excessive nitrogen and phosphorus loads that enter surface water (Duro, 2012). Runoff from agricultural land is the major cause in Northern countries. USA and Europe lost an enormous amount of sediment and fertile topsoil during the past century (Stoorvogel, 1995). Due to context driven reasons, pollution always appears differently. Meaningful differences exist between countries in terms of agroecological, social, political, and economic features. Such differences need to be considered when designing a pan-European scenario and mitigation approach. Nutrient runoff from agricultural land and its impact on environment and forestry are studied here. To monitor environmental consequences, nutrient loads, including organic and mineral phosphorus and mineral nitrogen, were considered. This pressure evaluates whether and to what extent prescribed environmental standards and the status of water bodies are met. Forest fire occurred since early 2002, and large forest areas in Latvia were affected. The research analyzed nutrients which were eluted from cropland that is adjacent to burned forest. Satellite remote sensing detects and monitors the surface property changes in various environments. Generally, the Earth surface is described by physical, geometric, and chemical parameters. There exist wavelength ranges, over which the differences in the energy radiation effectively describe surface feature changes.

Policy Implications

The spatial growth of agricultural land is jointly determined by multiple interrelated policy and market-related factors, and/or variables. The realized agricultural land use growth outcomes as a result of these various factors/views may help analyze current agricultural land use management policies, better learn the implications of policies, and identify potential actions that policymakers can take to seek desired growth developments (G Hailu & Brown, 2007). This modeling framework may be extended to assess the implications of alternative agricultural land management policies. For instance, a policy scenario with only one or a select few of the growth factors getting a substantial change while holding others constant could be tested. In addition, some variables could be exogenously moved toward predetermined values so that the implications of converging growth patterns can be derived under this scenario. A model form well suited to the specific purpose hypotheses needs to be selected. Different forms and specifications as well as estimation methods must be explored to select the proper format. The general approach as described in this framework can easily accommodate different modeling forms. However, because of the nature of the scope and context, coordination and cooperation among agricultural planners and land use management agencies and departments at all government levels (federal, state, and local) may be required for more cohesive modeling structure and approach (Duro, 2012). Agricultural growth and development in one geographic area impact agricultural land use patterns with or without local growth outcomes. Acknowledge interdependences in agricultural development in their actions. Local governments, authorities, and agencies are bound to act locally. Urban sprawl in rapidly urbanizing cities heavily affects farmland losses in adjacent, slower growing areas. Farmland protection/enhancement policies focus mostly on preserving as much agricultural land as possible in the county or area. Comprehensive cross-county and cross-state land use policy coordination initiatives may provide better outcomes in managing farmland losses.

1. Land Use Regulations

Land is one of the most important resources of earth as it is associated with agriculture, where food, fiber and forage are produced through cultivation. Land use pattern of a region is the outcome of the natural and socio-economic factors and their utilization by man in time and space. Land use pattern of an area is determined mainly by its physiological, topographical and socio-economic factors. Agriculture is made up of the products of the land and the chief land use in the world. Man's greatest need is for food. Without it, life of all form would perish on earth. It is against this background that the study examined change in land use and its effect on the amount of land available for agricultural production as basis for decisions on land use planning for sustainable agriculture. The study was carried out in Ido local government area. The area is under the derived savannah belt of Nigeria, which is one of the most fertile agricultural zones of the country with high farm production potentials. In view of the above, this study aimed to find out change in land use pattern and land use priority, land use pattern and its determinants, and land use planning strategies for sustainable agriculture. The study employed both ground and land-sat images of Oyo State for the years 1984, 2000 and 2010. The land use types identified included built up area (urban land use), agricultural land use (cultivated land, bush fallow, scrub/secondary forest, virgin forest), bare land (quarry), and water body. The images were classified using maximum likelihood, supervised classification and post-classification. With the loss of a total of 22267.461 hectares of agricultural farm land between 1984 and 2010, the trend must be checked. Some recommended strategies in view of the observed losses for sustainable agricultural production are elevation of urban land use regulations and change in public perception/future population to be accommodated (G Hailu & Brown, 2007).

2. Incentives for Sustainable Agriculture

This paper deals with the geographical aspects of agricultural policy. Policy makers are becoming aware of the need to fully understand the linkages among locations, processes, ecosystems and agricultural systems in carrying out this assessment. Nevertheless the existing tools still do not have the geographic transparency needed to assess properly the outcomes of policies. The validity of this approach is tested in southern Tuscany. After discussing the modelling framework which the analysis is based on, possible improvements and how to extend this experience to other applications were presented. Last but not least, results were presented and discussed regarding the policy outcomes of the current CAP application in the Mugello area as a whole. Data for the models used were obtained largely from various agencies and their coordination required a major effort. Future efforts will be mainly devoted to the assessment of spatially explicit environmental policy (Fastelli et al., 2017). Two dimensions of agricultural development, in terms of market access and intensity of land use, are examined among different climatic regions. Equilibrium of spatial growth is tested with comparative cross-sectional data across prefectures in Japan. A decomposition technique estimates agglomeration in the growth of agricultural land use as a simultaneous function of growth in number of farmers and land area per farmer. Income elasticity of organic farming, as a new agricultural segment, in Japan is also estimated with examined income-ratio affected growth. Discussion includes important implications of land use change for farmer mobility and structural transition of agriculture.

3. Community Engagement in Land Use Planning

In their study of community context, Axinn et al. focus on infrastructure changes for local schools and transportation networks, arguing that these developments affect environmental characteristics like land use. They develop a framework for how community characteristics can affect local land use, focusing on agricultural settings (G. Axinn et al., 1999). The underlying concern is important changes in environmental patterns that can arise from community characteristics. For example, rapid expansion of education in rural areas can impact the availability of agricultural labor, the reorganisation of agricultural production, and ultimately the amount of land converted from agriculture to other uses. A global concern is that local land use decisions are important factors in the preservation or destruction of the environment (Nickodem, 2015).

Future Directions in Agricultural Land Use Research

Local representative images provide important information about the geographical characteristics of agriculture. The dynamics of local agriculture is often examined through the analyses of geographic information such as cropping area, cropping pattern, and agricultural land use pattern. To obtain such information, various types of remote sensing data have been used increasingly. The improvement of results relies on the methodology used as well as on the performance of the equipment. Future work could focus on obtaining ancillary information and/or EO imagery capable of providing detailed land cover classes that allow the spatial disaggregation to be carried out in more detail. As different crop types require varying amounts of fertilizer, information on the amount of fertilizer applied per crop type could be estimated. Another example might involve using appropriate EO imagery and ancillary data to locate areas and extents of improved and unimproved pastures, feedlots, and other livestock operations, which could provide greater insights into the spatial distribution of livestock related land use intensity information.

While caution should still be exercised to keep results interpretable to an end user, the use of more refined datasets and methods could improve spatio-temporal representation of land use classes and granularity of relevant explanatory variables. Semi-automated approaches have been employed to extract local representative land use information. With the availability of communication technologies, crowdsourcing, and citizen engagement, recent responses related to the farmer's perspective have also been used as a powerful tool for collecting primary information on agriculture, the performance of which deserves further experimentation in different regions. It was expected that future studies will continue to examine higher levels of users' needs, the ultimate aim of which is to convert the products into actionable knowledge that will contribute to sustainable agricultural development (Duro, 2012) (Toshio & Eranga, 2015).

1. Emerging Technologies in Spatial Analysis

Technologies such as remote sensing and geographic information systems (GIS) have made substantial contributions to agriculture and land use modelling. There are large amounts of knowledge gained and publicly available data from the past two decades of R&D efforts on agricultural remote sensing and GIS (Duro, 2012). Satellite imagery, especially density satellite imagery, land use–land cover data, and meteorological data are publicly available to users, making considerable contribution to improved understanding on agricultural development monitoring and forecasting as well as agricultural practice effect evaluation. More importantly, several regional, country and world level crops yield forecasting systems using these data have been established, and R&D will focus on detailed sensitivity testing among themselves on and off field in the future. Considering the multi-level scales of space and time in modeling agricultural land use pattern, recent technological advances on spreading spatial panel data, the forefront research issue will be the usability of geospatial data. In particular, socio-economic factors derived from indirect observations and quantified by economic principle to explain the land use changes at the macro scale of regions and countries are not publicly available. Presently the collection is relied on manually and it is labour intensive, and the gathering exercise may not reach the desired source coverage. The semi-automated techniques developed on GIScience domain may be applied to sifting through search engines for new developments, smoothing the estimation processes and forming geographically distributed database networks.

2. Integrating Climate Change Adaptation

Analyses of climate change adaptation in agriculture using econometric models find no widespread sector consistencies. Current process-based crop models utilise climate-impact relationships that are based on historical data and fail to incorporate adaptation processes. Existing assessments of future agricultural productivity that account for the impact of higher levels of greenhouse gases do not consider changes in management or land use in response to climate change. Furthermore, given that past climate impact assessments are state dependent, adaptation responses need to be region and farm specific, thus hampering their integration in sector model. These models operate with generic response functions for climate impacts that do not consider adaptiveness, which is fundamental to characterise vulnerability to climate change. Hence, model structures, assumptions, and parameterisation in climate change impact assessment should be examined for their sensitivity and robustness (Reidsma et al., 2009). Little effort has so far gone into identifying those cases where tailoring of model structures, assessment methods, and output presentation would be likely to produce more robust assessments of climate impacts, and thus reduce uncertainty. Until such efforts have been undertaken, it is unlikely that agriculture would be integrated in many economy-wide assessments of climate change damages.

3. Cross-Disciplinary Approaches

Microeconomics is a mature research area that has a proven record of developing and estimating general equilibrium models of land use, with many agrarian applications. Macroeconomics has a rich search theoretic tradition that can be applied to the analysis of land use over space. Theoretical economic models of land use that take an equilibrium perspective and that can be simulated in random scatter-space (RS) with a representative agent have demonstrated information loss as macroeconomists move from Gordon's full speculative equilibrium to Alov's local static equilibrium. Environmental economics has explored how changes in property rights may lead to important alterations in the way land use adjusts to human inputs, and many new methods for data generation or processing have been developed in the econometrics tradition. Following this philosophy, a number of more advanced methodologies based on the Meta-Gaussian distribution and multilevel Monte Carlo (MLMC) simulation are proposed to deal with the limitations imposed by cartesian grids.

At the same time, agriculture has many aspects that are modelled as static and discontinuous. A more fruitful avenue to explore would lie in examining the temporal association between agricultural development, conversion, and sectoral focus change, going beyond the macro picture. Many literatures provide evidence that, at the macro level, economic development is usually accompanied by urbanisation and rise of the service sector. Accompanying a rich mix of experience from diverse contexts, mobile resources are often in wiringness to be put to work in many tasks, so the resource misallocation in both rural and urban settings would increase before growth efficiency improves and allocate resources optimally to respective tasks.

Conclusion

The analysis of geoinformation has a long tradition in property value research. The use of GIS in the analysis of agricultural land use and value patterns is still in its infancy. Given the necessity and potential of this approach to real estate research, many questions remain. For the analysis of agricultural land use patterns, detailed data on agricultural land use change on specific parcels is needed and new real estate support is necessary in order to coerce property value data from publicly available sources (Duro, 2012). The digitalisation of the entire property transfer process is still in its early stages also. Coordination among universities, industry and government would encourage existing data sources with a large feedback potential for GIS analysis. Considering both datasets, much work still needs to be done in order to understand the social and economic dimensions of and possibilities for spatially referenced agricultural land use change. Because of time constraints, it has not been possible to include a discussion of theoretical approaches on land use and value change. Given their important roles, all forms of agricultural landscape management should be included in the analysis. Identifying concerns specific to farmland would lead to an improved understanding of the issues surrounding land use and value change in this area. More specific research questions could also be developed, e.g. does opposition to agriculture differ with respect to its intensity, type, spatial concentration or governmental involvement?

These and many other questions could not be answered or even sufficiently addressed with the present analysis but could lead to richer insights into the type and reason for the ongoing transformation of the productive landscapes surrounding Amsterdam, one of the most fertile regions in the Netherlands in Dutch history. The importance of agricultural land use and value in a European context will increase over the next decades due to changing agricultural operating in the EU and the Lisbon Strategy.

Acknowledgement

The author expresses sincere gratitude to the Department of Geography, Sangameshwar College, Solapur (Autonomous), for their academic support and encouragement throughout the research process. Special thanks are extended to colleagues and students who provided insightful feedback and assistance during data collection and analysis. The contributions of all collaborators and institutions mentioned in the case studies are deeply appreciated.

Financial Support and Sponsorship

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

Ethical Considerations

This study is based on secondary data sources, published literature, and publicly available geospatial datasets. No human participants, animals, or personally identifiable information were involved in the research process. All case study data used were obtained from reliable, open-access repositories with proper citations. The research complies with ethical standards in academic publishing, and due diligence was observed to maintain academic integrity and avoid plagiarism.

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