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Agricultural land conversion and ecosystem services loss: a meta-analysis

Xiangzi Fang[1] · **Samane Ghazali**[2] · **Hossein Azadi**[5,6,7] · **Rytis Skominas**[4] · **Jürgen Scheffran**[3]

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Abstract

This study aimed at investigating the harm from ecosystem services (ESs) according to agricultural land conversion (ALC) by using meta-analysis. The results of meta-regression showed that spatiotemporal effects had significant influences on some ES losses, and the maximum spatial impacts were relevant to Asia and Europe. Moreover, the results of ALC rate coefficients in meta-regression indicated that three large losses of ES were related to soil erosion (0.314), air pollution (0.202), and climate change (0.161). Therefore, the ALC should be done at a suitable conversion rate to reduce ES losses. Accordingly, administrators are suggested to consider careful research planning for the ALC in the process of economic development. Other strategies highlighted the importance of ALC–ES interactions for human well-being, such as measuring the pricing of goods and services based on land resources, continuously monitoring illegal ALC, and imposing taxes on unplanned ALC.

Keywords Air pollution · Climate change · Economic development process · Land use · Soil erosion · Spatiotemporal effects

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✉ Xiangzi Fang
fangxz7688@gmail.com

[1] International Sakharov Environmental Institute, Belarusian State University, 220070 Minsk, Belarus

[2] Agricultural Economics, Shiraz University, Shiraz, Iran

[3] Research Group Climate Change and Security, Institute of Geography, University of Hamburg, Hamburg, Germany

[4] Bioeconomy Research Institute, Vytautas Magnus University, 44248 Kaunas, Lithuania

[5] Department of Economics and Rural Development, Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium

[6] Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Prague, Czech Republic

[7] Faculty of Environmental Science and Engineering, Babeș-Bolyai University, Cluj-Napoca, Romania

1 Introduction

In emerging nations, agriculture makes for a major portion of gross domestic product (GDP) (Dhahri & Omri, 2019). At the beginning of the economic development process, this sector overcomes both land use and national income (Wang et al., 2018a). Agriculture provides the livelihoods of the people in developing countries, like Malawi, Tanzania, and Zambia (Mdee et al., 2020). In addition, agricultural production performance has a major contribution to macroeconomic purposes, such as employment, poverty reduction, human resource expansion, and food security (Sheng & Song, 2018; Zhang et al., 2019). Population expansion, urbanization, industrialization, and soil erosion have all recently contributed to a major decline in agricultural areas (Kertész et al., 2019; Lasanta et al., 2019; Nassar et al., 2017). Furthermore, climatic conditions affect land use and agricultural land conversion (ALC) (Xu et al., 2019). Climatic factors are enhanced by population growth and human interventions in the natural environment through flood control, land drainage, and irrigation progress (Chabert & Sarthou, 2020; Mondal, 2019; Uitto, 2019). The ALC can be in the form of conversion of cultivated lands into other agricultural (e.g., commercial plantations, mixed farming, specialized horticulture, and pastoral farming), residential, and industrial operations (Kindu et al., 2016; Movahedi et al., 2021; Tripathi et al., 2019).

An ecosystem that is usually managed to produce crops or animal products is named an agricultural ecosystem (Shah et al., 2019). Ecosystems form the global life support system, where they are acknowledged as the foundation of human civilization and natural capital for long-term economic growth (Ellis et al., 2019; Islam et al., 2015). Ecosystem services (ESs) are a combination of different elements, including habitat, biological features, and different ecosystem processes (Li et al., 2021; Tripathi et al., 2019; Van der Biest et al., 2019). Natural ecosystems produce commodities and services that benefit humans directly or indirectly (Bottero et al., 2020; Motiejūnaitė et al., 2019). ES can be in the form of the conservation of rare species, water supply, or services that are difficult to see, such as soil conservation, water conservation, and storing carbon in a carbon pool (Li et al., 2020; Zhang et al., 2020). ESs that are critical to ensure individuals' sustainable livelihood focus on environmental communities to preserve them (Mafongoya & Sileshi, 2020).

Thus, this is crucial to evaluate the ES effects of land-use change (LUC). Several scholars (such as Islam et al., 2015; Tolessa et al., 2017; Tripathi et al., 2019) have studied LUC and its various impacts on ES loss. Liu et al. (2012) observed that LUC caused by human activities in the form of the loss of croplands and grasslands led to a fall in ES in Taiyuan City, China. Clerici et al. (2014) reviewed the conversion of coastal lands, including deforestation and reforestation and the loss of their capacity to provide ES in European stream coastal zones. According to Clerici et al.'s (2014) results, the loss of coastal areas' capacity to support ES has generally become above the converted surface ratio. Islam et al. (2015) determined the ALC in the Ganges delta and its impacts on ES. The findings revealed that agricultural areas have shrunk by 50% over the last 28 years, whereas wetlands have risen by 500% for shrimp cultivation. Agricultural land conversion necessitates significant investment. Thus, poor farmers are not able to change land use, and they face environmental impacts that affect their livelihoods in the long run (Islam et al., 2015). Balthazar et al. (2015) estimated the effects of land conversion on ES in the high Andean forest mountains in a fifty-year period. The conversion of forest land has been in the form of a change from net deforestation to net reforestation. Given the nature of forest cover conversion, increasing forest area is not related to improving ecological status. The total capability of the landscape to supply ES has declined. Tolessa et al. (2017) investigated the impact of land conversion in Ethiopia's central highlands from 1973 to 2015 on ES. During the 40-year period, forest lands decreased by 54.2%, and settlements, bare lands, shrubs, and arable lands increased significantly with ES 3.69 million USD loss due to LUC. Tripathi et al. (2019) evaluated ES loss of LUC during a 27-year time series in eastern India by satellite imagery. During the period of study, woodland and agronomical lands reduced by 22.5 and 17.2%, respectively, while the value of ES per km^2 in agricultural lands was reported to be higher than forest use.

While prior research looked at the influence of ALC on ES in different locations in the form of case by case, the worldwide originality of this study is that it quantifies the effect sizes over the world. The main aim of the current paper was to review original studies on the ES impacts resulting from the ALC and to evaluate such impacts using a meta-regression on the spatial and temporal scales. Two primary research questions are as follows:

How much is the ES loss over time and in different continents?

How do farmers whose farmland has been converted lose the ES during the economic development process?

2 Agricultural land conversion–ecosystem services interaction: a conceptual framework

The land is a basic input for producing crops along with labor and capital in the economy, which is the main factor for settlement and food production (Meyfroidt et al., 2019; Zhang et al., 2016a). Thus, land, which is the main driver of agricultural economies, has considerable ES benefits (Paudyal et al., 2019). Agricultural land is arable land for permanent crops or pastures. The crops remain on the ground for a long time and do not need to be replanted after each harvest (Oliveira et al., 2017). The ALC is also described as the use of arable property for non-agricultural uses, such as residential, industrial, and commercial ones during the economic growth process (Azadi et al., 2011, 2016; Rondhi et al., 2018; Teshome, 2014; Ustaoglu & Williams, 2017). Such LUC process has widely occurred in the current economic development and increase in population (Hu et al., 2019; Peerzado et al., 2018; Toure et al., 2018). Currently, crop production occupies about 11% (about 1.4 thousand million hectares) of the global surface area (about 13 thousand million ha), including arable land and territory under permanent crops. This surface represents over a third (37.6%) of the land suitable for crop production (Fitton et al., 2019). The ALC, which is the main type of land conversion, may lead to issues such as the harm from agricultural land and natural environment degradation (Pang et al., 2019; Safaei et al., 2019). Agriculture, cropping patterns, and agricultural management approaches also significantly affect climate variation, availability of water, and soil quality (Abdalla et al., 2019; Azadi et al., 2016, 2020; Barão et al., 2018). Agricultural land is an essential source of livelihood for rural households as it serves as the basis of their nutrition, income, housing, and social rights (Elver, 2019; Guo et al., 2019). Therefore, accurate planning on the ALC is necessary for land-use policymakers.

Humans and their surrounding environment are affected by land transformation in the agricultural sector, which is affected by various variables (Azadi et al., 2016; Omrani et al., 2015; Yurui et al., 2019). The extensive conversion of agricultural land has serious impacts on the environment and agricultural products (Alexander et al., 2019; Marques et al., 2019). Thus, the ALC to other uses has been prevented by many countries (Van der

Ven et al., 2018). The widespread agricultural land conversion represents a future crisis for agriculture and rural communities (Calicioglu et al., 2019; Rondhi et al., 2019).

The literature on the ALC explains the drivers influencing the expansion of industrial regions. In order to study economic development, there are two groups of theories including microeconomic theory on LUC (Bockstael, 1996; Jiang & Zhang, 2016) and the bid-rent model (Gao et al., 2020). Indeed, the microeconomic theory states that agricultural land conversion during development is the result of individual landowners' decisions to maximize their anticipated income (Wahyudi et al., 2019). Spatial land-use models are one of the powerful tools based on microeconomics to understand spatial concepts in land-use choices (Gerber et al., 2018; Jiang & Zhang, 2016). The bid-rent model uses spatial land-use models to convert a variety of lands, including agriculture and nature, industrial development, and urbanization (Clay & Valdez, 2017; Gao et al., 2017a).

ES is divided into four main groups: provision (e.g., water production), adjustment (such as climate control), patronage (like oxygen production), and cultural features (i.e., recreational benefits) (Arowolo et al., 2018; Zhang et al., 2016b). Losing the ES is described as a loss in the services, an ecosystem, a certain geographic area, or the whole Earth (De Carvalho & Szlafsztein, 2018; Maron et al., 2017; Xie et al., 2018). The Millennium Ecosystem Assessment (MEA) is an international program planned to meet the requirements of decision-makers for scientific information concerning the impacts of ecosystem change on human welfare. The MEA was concluded that almost 60% of ES have been degraded (Gómez-Baggethun et al., 2019; Papanastasis et al., 2015). The average loss of ecosystem benefits is considered to be $12 trillion per year on a worldwide basis due to LUC (Costanza et al., 2014; Guo et al., 2022).

LUC leads to the loss of natural ecosystems (Crespin & Simonetti, 2016; Wang et al., 2018b). During the process of economic development, which is accompanied by deforestation, urbanization, industrial agriculture, and other human activities, the natural landscape of rural regions changes in developing countries (Xiao et al., 2018). In addition, such LUC influences ES (Fig. 1), which can also have extensive and long-term impacts (Han et al., 2017).

Farms are suitable and valuable habitats for many species of animals (Herzog et al., 2017); however, intensive agriculture has major impacts on the natural ecosystem (Ribeiro & Šmid Hribar, 2019). Policies governing land use and the conversion of agricultural lands can have an impact on water quality and cause water pollution (Camara et al., 2019; Gao

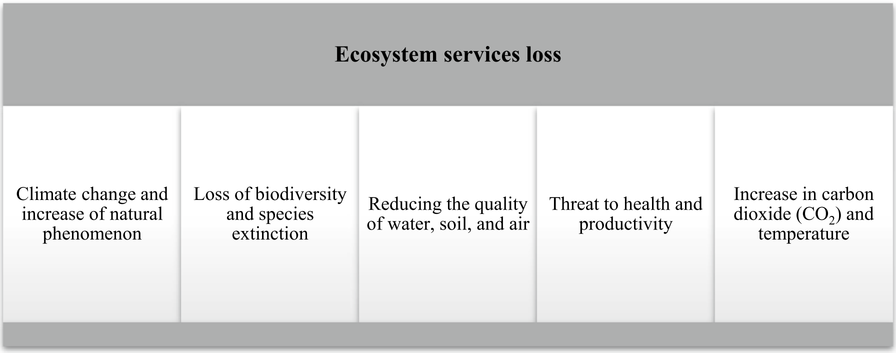


Fig. 1 ES loss due to the ALC. *Source* Han et al. (2017)

et al., 2017b; Razali et al., 2018). In agricultural lands, runoff has been recognized as the primary reason for water contamination (Uribe et al., 2020). In addition, the use of land for other purposes put rare species and thus biodiversity at risk of extinction (Ramachandran et al., 2018).

Trees provide a variety of ES, including biodiversity conservation, vital habitat protection, carbon sequestration, runoff control, soil erosion reduction, and flood risk reduction (Kibria et al., 2017; Reed et al., 2017). By developing the urbanization and industrialization, such valuable ES is reduced or eliminated (Xie et al., 2018). Deforestation, for example, has significantly changed the vegetation cover of the land (Aguiar et al., 2016). This vegetation change can alter the global carbon dioxide (CO_2) concentration, raise the temperature, and affect the climate by changing the energy balance at the surface (Azadi et al., 2020). Thus, with the change of climatic conditions, the number and severity of environmental phenomena increase (Brooks, 2013; Grillakis, 2019).

Urbanization has been linked to a number of environmental challenges, including deteriorating air, water, and soil quality (Lyu et al., 2018). Runoff in those regions contains toxic pollutants and leads to water sources pollution (Müller et al., 2020). Therefore, rapid urbanization is recognized as the most important cause of biodiversity loss and species extinction (Le Roux et al., 2019). In addition, such a rapid process poses a serious threat to health and productivity (Chen et al., 2017; Miao & Wu, 2016).

3 Research methodology

A meta-analysis was used in this research to synthesize the ALC's ES loss. Actuarial combination of outcomes from numerous original papers is known as a meta-analysis, and it is used to address new challenges (Pigott & Polanin, 2020). The meta-analysis includes a

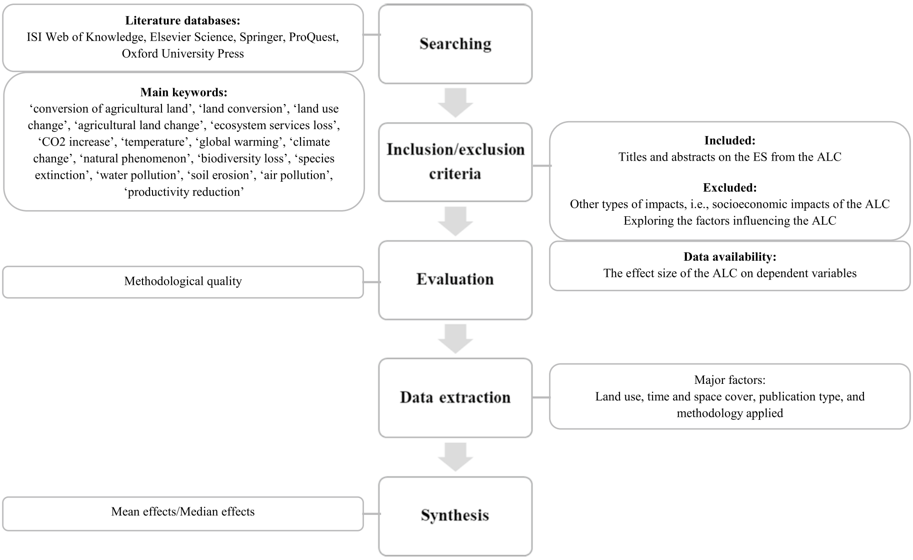


Fig. 2 The flowchart of research methodology steps

quantitative examination of the validity of the correlation proposed in the original papers across a wider scientific literature.

3.1 Specific structure of meta-analysis

Following the studies of Vesco et al. (2020) and Woodcock et al. (2014), Fig. 2 depicts the step-by-step summary of the employed approach. Five stages were used in this study's meta-analysis of original articles.

Various databases, such as ISI Web of Knowledge, Elsevier Science, and Springer, were thoroughly searched for original papers in the first stage from 2000 to 2020. Furthermore, the 'conversion of agricultural land' was the primary keyword as well as other words like 'land conversion,' 'land use change,' and 'agricultural land change.' These keywords were then combined with 'ecosystem services loss,' 'CO_2 increase,' 'temperature,' 'global warming,' 'climate change,' 'natural phenomenon,' 'biodiversity loss,' 'species extinction,' 'water pollution,' 'soil erosion,' 'air pollution,' and 'productivity reduction.' In the initial search, 1,784 have original papers.

Some factors for initial paper inclusion and exclusion were used in the second stage. With a focus on the ES loss of the ALC, titles and abstracts of articles also were extracted. Dependent variables in the meta-analysis were specified as productivity reduction, biodiversity loss, CO_2 rise, soil erosion, climate change, air pollution, and water pollution (Table 1). Hence, the papers dealing with other types of impacts, i.e., socioeconomic impacts of the ALC, were excluded, and papers exploring the factors influencing the ALC were also excluded. Thus, 58 journal articles were resulting as a consequence of this step. However, 58 original papers used the 'data availability' condition on various ESs. In the original studies, reporting the impact size of the ALC on various ES was necessary. Therefore, due to the availability of quantifiable information regarding effect sizes, the study was reduced to 43 pieces.

Step 3 should explicitly evaluate the source papers' method. In the present meta-analysis, an independent variable (namely, the component of the methodology employed) was applied to assess the quality of the method (Table 2). The statistical parameter Q-value was also applied to take consistent impact estimates and prevent the heterogeneity issue (that frequently happens in meta-analysis studies). Utilizing the original published data and sample size from the relevant study, the average impact sizes were determined (Meemken, 2020).

Table 1 Explanation of dependent variables. *Source* Han et al. (2017) and Meemken (2020)

Variable	Explanation
Productivity reduction	Decrease in the efficiency of agricultural production
Loss of biodiversity	Endangered rare species due to the conversion of agricultural lands
CO_2 increase	Increased concentration of CO_2 as a result of altered vegetation
Soil erosion	The degradation of the upward layer of land according to the reduction in vegetation
Climate change	Increasing the number and severity of environmental phenomena
Air pollution	Decreased air quality as a result of declining agricultural land and urbanization
Water pollution	Reduction of water quality due to the conversion of agricultural lands or runoff

Table 2 Explanation of explanatory variables. *Source* Narayanan et al. (2020) and Pigott and Polanin (2020)

Factor	Variable	Explanation
Land use	The ALC rate	Fluctuations in the ALC
Time	Data gathering year	Data gathering from 2000 to 2020
Space	Asia	The original article performing in Asia
	Europe	The original article performing in Europe
	America	The original article performing in America
	Africa	The original article performing in Africa
Publication type	ISI publication	The original article publishing in an ISI Journal
Methodology applied	Appropriate method	The original article capturing unobserved heterogeneity

The fourth stage involved extracting data from 43 chosen source articles. Several key factors were specified to classify the explanatory variables in Table 2, taking into consideration the methodologies by Narayanan et al. (2020) and Pigott and Polanin (2020). The following elements were included in each original paper (Table 3).

Land use, space cover and time, type of publication, and applied methodology. The qualitative information for each component was combined in the first stage. Second, each factor's aggregated datum was stated (based on dummy/continuous variable). The next step involved giving values one or zero to a dummy variable if the study met a certain attribute or not.

The mean effects are finally calculated using meta-regression in stage 5, and the quantitative effects in the median are synthesized for studies. Moreover, this study included peer-reviewed, foreign journal articles in English that investigated into how the ALC affected ES loss in developing countries. It is worth mentioning that the above-mentioned steps to collect data from the original documents were completed in September 2020. The collection of source papers is displayed in Table 1.

3.2 Quality assessment of the meta-analysis

To assess the meta-analysis, the scoring criteria (in Table 4) contained major criteria and sub-criteria followed by O'Leary et al. (2016). Based on how the sub-criteria were handled, scores of 3, 1, and 0 were assigned. The following are the main criteria:

(1) Protocol: That is a paper written before a meta-analysis is conducted. It outlines the subjects, the process for finding original papers, the context for the meta-analysis, and the standards for selecting papers for inclusion. The process should specify how to extract and synthesize the data as well as how to evaluate the substance of each original document. A protocol is examined before the technique is completed to make the research resistant to future changes (Pigott & Polanin, 2020).
(2) Searching: There are three essential elements to a successful search for original articles. It should be: (a) comprehensive (finding the most original papers), (b) systematic (using a set of guidelines and conducting frequent searches), and (c) transparent (providing users with information on the search strategy) (Turkeš et al., 2021).
(3) Inclusion/exclusion criteria: Our initial thorough search found numerous original papers. The articles should then be assessed to see if the meta-analysis can use them.

Table 3 Collecting original papers

Author (year)	Title	Region
Reidsma et al. (2006)	Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK
Lichtenberg and Ding (2008)	Assessing farmland protection policy in China	China
Martínez et al. (2009)	Effects of land use change on biodiversity and ecosystem services in tropical montane cloud forests of Mexico	Mexico
Eigenbrod et al. (2011)	The impact of projected increases in urbanization on ecosystem services	Britain
Liu et al. (2012)	An ecosystem service valuation of land use change in Taiyuan City, China	China
Pérez-Vega et al. (2012)	Comparing two approaches to land use/cover change modeling and their implications for the assessment of biodiversity loss in a deciduous tropical forest	Mexico
Clerici et al. (2014)	Land-cover change dynamics and insights into ecosystem services in European stream riparian zones	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK
Knox et al. (2015)	Agricultural peatland restoration: effects of land-use change on greenhouse gas (CO_2 and CH_4) fluxes in the Sacramento-San Joaquin Delta	The USA
Tadesse et al. (2014)	Prospects for forest-based ecosystem services in forest-coffee mosaics as forest loss continues in southwestern Ethiopia	Ethiopia
Azadi et al. (2016)	Agricultural land conversion drivers in Northeast Iran: Application of structural equation model	Iran
Islam et al. (2015)	Implications of agricultural land use change to ecosystem services in the Ganges delta	South Asia
Song and Deng (2015)	effects of urbanization-induced cultivated land loss on ecosystem services in the North China Plain	China
Aguiar et al. (2016)	Land use change emission scenarios: Anticipating a forest transition process in the Brazilian Amazon	Brazil

Table 3 (continued)

Author (year)	Title	Region
Crespin and Simonetti (2016)	Loss of ecosystem services and the decapitalization of nature in El Salvador	El Salvador
Kindu et al. (2016)	Changes of ecosystem service values in response to land use/land cover dynamics in Munessa–Shashemene landscape of the Ethiopian highlands	Ethiopia
Zhang et al. (2016b)	Awareness and perceptions of ecosystem services in relation to land use types: Evidence from rural communities in Nigeria	Nigeria
Chen et al. (2017)	Decreasing Net Primary Productivity in Response to Urbanization in Liaoning Province, China	China
Gao et al. (2017b)	The impact of land-use change on water-related ecosystem services: A study of the Guishui River Basin, Beijing, China	China
Han et al. (2017)	A long-term analysis of urbanization process, landscape change, and carbon sources and sinks: A case study in China's Yangtze River Delta region	China
Herzog et al. (2017)	European farm scale habitat descriptors for the evaluation of biodiversity	Austria, Bulgaria, France, Germany, Hungary, Italy, Netherlands, Norway, Spain, Switzerland, Wales
Nassar et al. (2017)	Agricultural land use change and its drivers in the Palestinian landscape under political instability, the case of Tulkarm City	Palestine
Oliveira et al. (2017)	Agricultural land use change in the Brazilian Pampa Biome: The reduction of natural grasslands	Brazil
Tolessa et al. (2017)	The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia	Ethiopia
Arowolo et al. (2018)	Assessing changes in the value of ecosystem services in response to land-use/land-cover dynamics in Nigeria	Nigeria
De Carvalho and Szlafsztein (2018)	Urban vegetation loss and ecosystem services: The influence on climate regulation and noise and air pollution	Brazil
Kim and Arnhold (2018)	Mapping environmental land use conflict potentials and ecosystem services in agricultural watersheds	Korea

Table 3 (continued)

Author (year)	Title	Region
Lyu et al. (2018)	Impacts of urbanization on ecosystem services and their temporal relations: A case study in Northern Ningxia, China	China
Peerzado et al. (2018)	Land use conflicts and urban sprawl: Conversion of agriculture lands into urbanization in Hyderabad, Pakistan	Pakistan
Ramachandran et al. (2018)	Long-term land use and land cover changes (1920–2015) in Eastern Ghats, India: Pattern of dynamics and challenges in plant species conservation	India
Rondhi et al. (2018)	Agricultural land conversion, land economic value, and sustainable agriculture: A Case study in East Java, Indonesia	Indonesia
Wang et al. (2018a)	Effects of the Chinese arable land fallow system and land-use change on agricultural production and on the economy	China
Wang et al. (2018b)	Projections of future land use changes: Multiple scenarios-based impacts analysis on ecosystem services for Wuhan city, China	China
Xiao et al. (2018)	Spatial variability of local rural landscape change under rapid urbanization in eastern China	China
Xie et al. (2018)	Projecting the impacts of urban expansion on simultaneous losses of ecosystem services: A case study in Beijing, China	China
Gómez-Baggethun et al. (2019)	Changes in ecosystem services from wetland loss and restoration: An ecosystem assessment of the Danube Delta (1960–2010)	Romania
Guo et al. (2019)	Interactions between sustainable livelihood of rural household and agricultural land transfer in the mountainous and hilly regions of Sichuan, China	China
Kertész et al. (2019)	Effect of land use change on ecosystem services in Lake Balaton Catchment	Hungary
Pang et al. (2019)	Understanding the linkages between production activities and ecosystem degradation in China: An ecological input–output model of 2012	China

Table 3 (continued)

Author (year)	Title	Region
Paudyal et al. (2019)	Spatial assessment of the impact of land use and land cover change on supply of ecosystem services in Phewa watershed, Nepal	Nepal
Ribeiro and Šmid Hribar (2019)	Assessment of land-use changes and their impacts on ecosystem services in two Slovenian rural landscapes	Sloveni
Rondhi et al. (2019)	Agricultural land conversion and food policy in Indonesia: Historical linkages, current challenges, and future directions	Indonesia
Safaei et al. (2019)	Assessing the impacts of land use and land cover changes on soil functions using landscape function analysis and soil quality indicators in semi-arid natural ecosystems	Iran
Tripathi et al. (2019)	Ecosystem services in different agro-climatic zones in eastern India: Impact of land use and land cover change	India

Table 4 Scoring criteria for the quality assessment of the meta-analysis. *Source* O'Leary et al. (2016) and Woodcock et al. (2014)

Criterion	Sub-criterion	Explanation	Score
Protocol	Was a former protocol available for a statement before the review was conducted?	A former protocol is available	3
		Not determined	1
		No former protocol is available	0
Searching	Does the search for papers has a broad scope of databases?	Minimum of three sources	3
		Two or one relevant sources	1
		Database is not documented	0
	Are the search fields clearly specified?	Major keywords and Boolean operatives	3
		Major keywords or Boolean operatives	1
		Search is not clearly specified	0
Including	Does the review apply clearly evidenced inclusion criteria to all papers?	Precisely determine all criteria	3
		Quite obvious goal	1
		Not determine	0
	Does the review show that inclusion/exclusion intentions are iterable?	Inclusion intentions are taken by above one person and results are indicated	3
		Inclusion decisions are taken by above one person but results are not indicated	1
		Iterability is not tested	0
	Are the final intentions for including original papers transparent?	List included studies and explain the reasons for excluding	3
		List included studies but do not explain the reasons for excluding	1
		Lack of included papers list	0
Evaluation	Does the review specify an acute assessment of the method of any papers?	Assessing the method of each paper by the certain criterion	3
		Generally assessing the method of all papers	1
		Not assessing the method of papers	0
	Are papers weighted based on the quality of the methodology?	Weighting diversity in the quality of papers	3
		Altering the quality of papers but not weighting them	1
		Not altering the quality of papers	0

Table 4 (continued)

Criterion	Sub-criterion	Explanation	Score
Extraction	Is data extraction recorded, iterative ability, and consistent?	Systematically specifying the extraction way	3
		Specifying the extracting metrics	1
		Not specifying the extraction way and the metrics	0
	Are the extracted data stated for any papers?	Quantitatively stating the selected outcome metrics (or the effect size)	3
		Quantitatively stating several outcome metrics	1
		Not stating outcome metrics quantitatively	0
Synthesis	Is a quantitative synthesis performed?	The ES losses of the ALC from papers are synthesized quantitatively and compared statistically	3
		The ES losses of the ALC from paper are synthesized quantitatively but not compared statistically	1
		Data synthesis is qualitative	0
	Is heterogeneity the effect of intervention/exposure assessed statistically?	Performing the statistical test of Q-value	3
		Not specified	1
		Not performing the statistical test	0
	Is the possible publication bias appraised in the synthesis?	Evaluating the likelihood of publication bias statistically	3
		Including syntheses that assess the likelihood of publication bias subjectively	1
		Not addressing publication bias	0

Setting inclusion and rejection criteria for studies is crucial at this point and may impact the findings of meta-analyses. Open criteria should be used to choose which original papers to include in the meta-analysis (Pigott & Polanin, 2020).

(4) Evaluation: The methodology used in the original papers varied, and this must be attended in the review. For clear assessment, the methodology from the original article should be used (Vesco et al., 2020).

(5) Data extraction: Even if meeting the identical issue, the amount and quality of effect sized vary considerably. Meta-analysis implies deciding what results to pursue and how to calculate the results. Such decisions could have an effect on the findings. As a consequence, the data extraction could be introduced explicitly, and measures should be consistent across studies (Vesco et al., 2020).

(6) Synthesis: The aim of this review is to outline the extent of the ALC's effect on the ES. The technique for the synthesis of original articles differs widely, and certain methods are more efficient at reducing measurement bias. Among the most successful methods are the mean and median effects (Klümper & Qaim, 2014).

4 Results

4.1 Data description

According to the review of 43 original papers, the maximum rate of the ALC was 87%, and the distribution of conversion rate of agricultural land is shown in five different groups in Fig. 3. The two groups of 0–20% and 21–40% rates of the ALC included 10 and 12 studies, respectively. Then, 16 papers show that the ALC rate was in the range of 41–60%. Next groups of rates of the ALC had fewer studies, with four studies in the 61–80% group and one study in the 81–100% group.

Based on the spatial distribution, 43 original studies were performed in 36 countries over four continents (Fig. 4). Most of the projects (20 papers; 46.5%) were determined in

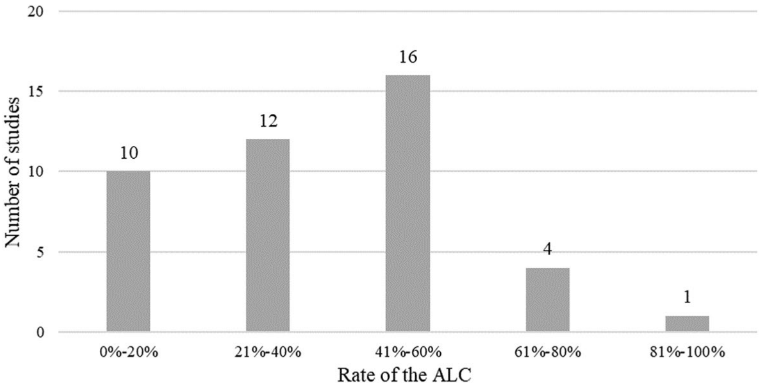


Fig. 3 The distribution of the rate of ALC

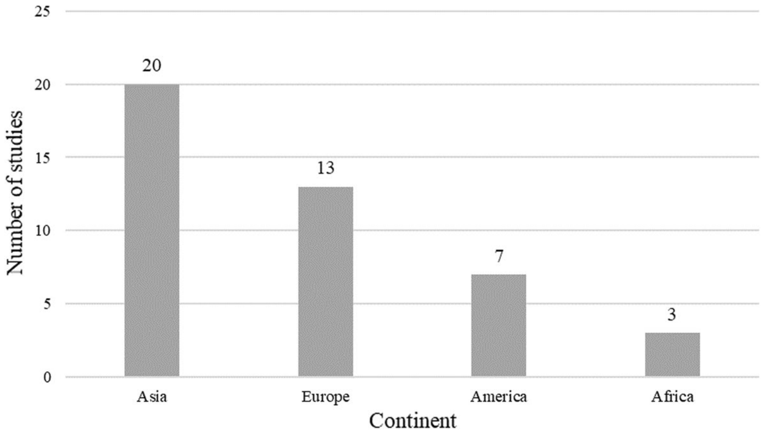


Fig. 4 The spatial distribution in different continents

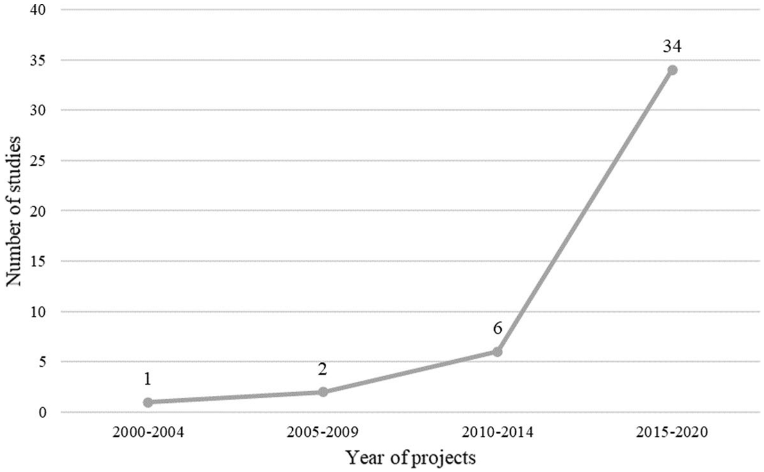


Fig. 5 The temporal trend based on the paper year

Asia, which were mostly distributed in China (9 papers; 20.9%). Furthermore, 13 studies (30.2%) were performed in Europe. Only 7 (16.3%) and 3 (7%) papers were performed in America and Africa, respectively.

Figure 5 indicates the temporal trend based on the year of the projects. The year of projects has an upward trend. During the two periods of 2000–2004 and 2005–2009, a small number of articles were performed 1 (2.3%) and 2 (4.6%), respectively, while 34 articles (79.1%) were performed in the period 2015–2020. As shown in Fig. 5, the number of ALC research was severely added after 2014.

The criterion of ISI-indexed paper was used to evaluate the original articles' quality. As a consequence, 40 articles (93%) were accepted for publication in an ISI journal. Moreover, two original papers employed panel models to account for unobserved heterogeneity in their results. As a result, these investigations were attended objectively (Zyphur et al., 2019).

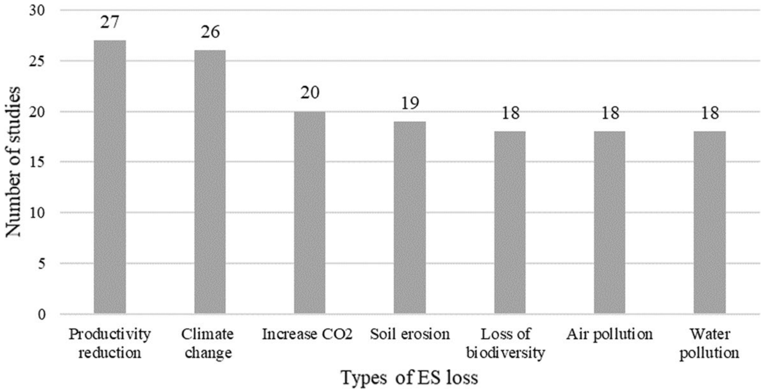


Fig. 6 The distribution of ES losses resulting from the ALC

4.2 Ranking of types of ecosystem services (ES) losses

The distribution of ES losses resulting from the ALC is displayed in Fig. 6. A paper may have examined several ES losses resulting from the conversion of agricultural lands. Among the considered variables of ES losses, two variables of productivity reduction and climate change have the highest distributions that, respectively, include 27 and 26 papers (62.8 and 60.5%). Furthermore, the least distribution of the ES losses is related to three variables of loss of biodiversity, air pollution, and water pollution with the number of 18 papers (41.9%).

4.3 Meta-regression results

Meta-regression is a scientific approach for quantitatively reviewing and synthesizing documented-based research (Doucouliagos, 2016). Table 5 demonstrates the variables that influence meta-regressions. As shown in Table 5, R^2 varies from 0.36 (biodiversity loss) to 0.68 (climate change), indicating the proportion of the variance described by including explanatory factors in meta-regressions.

According to the results of Table 5, the main variable of the ALC rate has significant effects on the productivity reduction (mean effect: −0.669 at 1% significance level), and loss of biodiversity (mean effect: 0.082 at 10% significance level). Furthermore, other effects are CO_2 increase (mean effect: 0.104 at 10% significance level), soil erosion (mean effect: 0.314 at 1% significance level), climate change (mean effect: 0.161 at 1% significance level), air pollution (mean effect: 0.202 at 5% significance level), and water pollution (mean effect: 0.104 at 10% significance level). The next subsection describes in detail the ES losses due to ALC. The data collection year has a substantial positive impact on three ES losses of soil erosion (mean effect: 0.004 at 5% significance level), climate change (mean effect: 0.005 at 1% significance level), and air pollution (mean effect: 0.005 at 1% significance level). It implies that if the original study used current data, the ALC would produce less than 1% rise in land erosion, climate change, and air pollution. However, in recent years, other ES losses, including productivity reduction, loss of biodiversity, CO_2 increase, and water pollution, are not affected by the year as the coefficient of those variables is not significant.

Table 5 Factors influencing ES loss in meta-regressions

Factor	Variable	ES loss						
		Productivity reduction	Loss of biodiversity	CO_2 increase	Soil erosion	Climate change	Air pollution	Water pollution
Land use	The ALC rate	− 0.669***	0.082*	0.104*	0.314***	0.161*	0.202**	0.104*
Time	Year of project	− 0.007	0.002	− 0.002	0.004**	0.005***	0.005***	− 0.001
Space	Asia	1.079	2.719	0.119	7.586**	11.192***	11.672***	2.021
	Europe	0.914	2.609	0.187	7.711**	11.037***	11.536***	2.108
	America	1.235	2.998	0.073	7.560**	10.989***	11.548***	2.120
	Africa	0.915	2.398	0.179	7.019**	11.011***	11.507***	2.184
Publication type	ISI publication	0.448***	0.458***	0.463***	0.379***	0.560***	0. 567***	0.546***
Methodology applied	Appropriate method	0.225	0.123	0.326*	0.178	0.234	0.421	0.361
Q-value		7.84	0.45	6.37	1.01	0.53	2.90	2.74
R^2		0.47	0.36	0.57	0.52	0.68	0.48	0.45
Number of observations		42	34	61	52	75	45	38

Asterisks are for statistical significance level: * for 10%, ** for 5% and *** 1%

For spatial effects, the impact of the ALC on some ES losses is significant across different continents. Accordingly, studies performed on the ALC in Asia show significant impacts on soil erosion (mean effect: 7.586 at 5% significance level), climate change (mean effect: 11.192 at 1% significance level), and air pollution (mean effect: 11.672 at 1% significance level). It means that if the original paper was performed in Asia, the ALC would cause an about 8, 11, and 12% increase in soil erosion, climate change, and air pollution, respectively. In Europe, studies that performed on the ALC show significant impacts on soil erosion (mean effect: 7.711 at 5% significance level), climate change (mean effect: 11.037 at 1% significance level), and air pollution (mean effect: 11.536 at 1% significance level). It means that if the original paper was performed in Europe, the ALC would cause an about 8, 11, and 11% increase in soil erosion, climate change, and air pollution, respectively. Furthermore, studies performed on the ALC in America show significant impacts on soil erosion (mean effect: 7.560 at 5% significance level), climate change (mean effect: 10.989 at 1% significance level), and air pollution (mean effect: 11.548 at 1% significance level). It means that if the original paper was performed in America, the ALC would cause an about 8, 11, and 11% increase in soil erosion, climate change, and air pollution, respectively. In Africa, studies that performed on the ALC show significant impacts on soil erosion (mean effect: 7.019 at 5% significance level), climate change (mean effect: 11.011 at 1% significance level), and air pollution (mean effect: 11.507 at 1% significance level). Thus, when paper was performed in Africa, the ALC would cause about 7, 11, and 11% increase in soil erosion, climate change, and air pollution, respectively.

The publication type factor (explained in Table 2) states about 0.45, 0.46, 0.46, 0.38, 0.56, 0.57, and 0.55% of the variations in effect sizes of productivity reduction, loss of biodiversity, CO_2 increase, soil erosion, climate change, air pollution, and water pollution (Table 5). Furthermore, the coefficients of the methods used in Table 5 are not significant, implying that the original studies that captured unobserved variability in their data have no significant impacts on ES loss.

4.4 Ecosystem services (ES) loss of the ALC

The results of Table 5 showed that increasing the conversion rate of agricultural land does not decrease productivity reduction because its coefficient is negative (mean effect: -0.669 at 1% significance level). Therefore, a 1% increase in the ALC rate improves agricultural productivity by about 0.67%. Although farms become smaller as LUC increases from agricultural to non-agricultural during the process of economic development, technological improvements in the form of improved seeds and chemical fertilizers prevent productivity declines. In addition, a 1% increase in the ALC rate causes a raise of more than 0.08% in the loss of biodiversity, which is in the form of the loss of rare biological species. During economic development and the ALC, farming activities decrease, and consequently, the absorption of CO_2 from the atmosphere is decreased by plants. Thus, the concentration of this gas in the atmosphere increases. According to Table 5, a 1% increase in the ALC rate causes an above 0.10% increase in CO_2. Moreover, a 1% increase in the conversion rate of agricultural land reduces soil quality and increases soil erosion by about 0.31% (Table 5). Another loss of the ES is that a 1% increase in the ALC rate increases the probability of climate change by 0.16% (Table 5). Finally, a 1% increase in ALC leads to an increase of more than 0.20 and 0.10% in air pollution and water pollution, respectively (Table 5).

Furthermore, Fig. 7 indicates the impacts of ALC on ES losses in median. The impact of the ALC on productivity reduction is significantly negative (median effect: −0.34 at

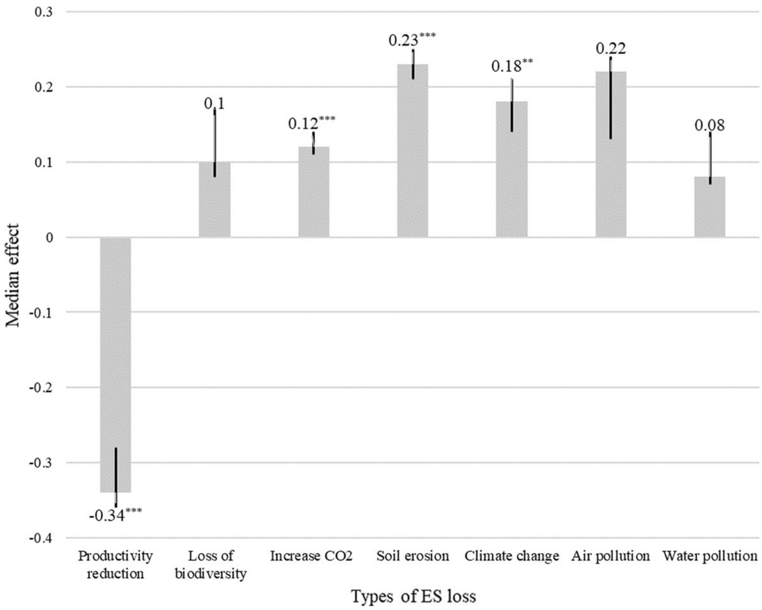


Fig. 7 Median effects of the ALC on ES losses. Error bars illustrate standard errors

1% significance level). It means that increasing the ALC rate causes a 0.34% increase in agricultural productivity per hectare on remaining lands. In addition, the ALC increases significantly the median of CO_2, soil erosion, and climate change by 0.12, 0.23, and 0.18%, respectively (Fig. 7). Thus, the most positive effect of the ALC is identified on the median of soil erosion. The average effects of ALC on soil erosion are about 48% greater than the increase in CO_2 and also about 22% greater than climate change. The ALC does not affect other types of ES losses in the median, such as harm from biodiversity, and air and water pollution due to the large standard errors.

4.5 Reporting the quality of meta-analysis

Table 6 provides an overview of the 13 sub-criteria that make up the present meta-analysis of the worldwide ES losses caused by ALC. Ten sub-criteria in this respect reported a score at 3, indicating the high precision of the present meta-analysis. The ESMC (Ecosystem Services Market Consortium) protocol, which attributes a monetary value to the four environmental advantages that can be produced on agricultural property, is an existing priori protocol that meets the first sub-criteria. All of these benefits, e.g., increasing soil carbon, reducing net GHG emissions, and increasing water quality and quantity, come from good soil health (Salzman et al., 2018). Then, more than three databases were nominated, from which original papers were obtained, and the keywords used to perform the regular search were prepared. First, the criteria for original papers were carefully determined (Fig. 2), then several individuals made decisions regarding inclusion, and finally, the inventory of studies that were contained was reported in Table 3 along with an explanation of why some papers were excluded (Fig. 2). Based on the assessment criterion, the method of the paper was assessed by the methodology implemented factor (Table 2). Moreover,

Table 6 The scores for assessing meta-analysis quality

Sub-criteria	Protocol	Searching1	Searching2	Including1	Including2	Including3	Evaluation1	Evaluation2	Extraction1	Extraction2	Synthesis1	Synthesis2	Synthesis3
Score	3	3	1	3	1	3	3	1	3	3	3	3	3

the difference in the method quality of studies was assessed in meta-regressions (Table 5). Additionally, Table 2 shows the metrics for giving information from studies, and meta-regressions were used to determine the average effect of the ALC on ES losses. The ES loss of the ALC from each source article was quantitatively synthesized and statistically compared as a synthesis criterion (Fig. 7). Additionally, the outcomes of the Q-value test indicate that the effect of the ALC on ES loss is not significantly diverse (Table 5). Finally, Fig. 8 displays the test of the publishing bias for the ES loss of the ALC. When the results of original papers are synthesized, the test is symmetrical for all ES, as shown in Fig. 8. The test consequently indicates that the bias was not in summarizing the findings of the studies. As a result, because effects are specifically assessed, the reliability of studies in total and the reviews in specific can be considered.

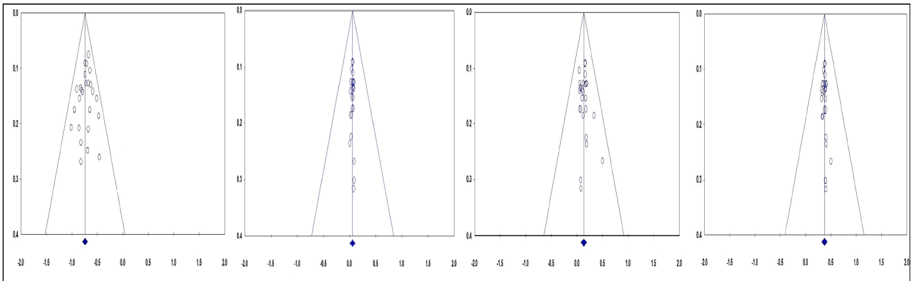
5 Discussion

5.1 The spatiotemporal effects on the ES losses

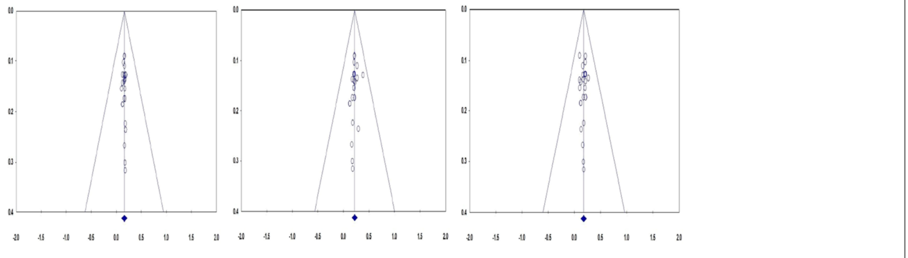
The significance of the temporal effects on ES losses in meta-regression results shows that those losses have significant changes over time. Thus, the ES losses, including soil erosion, climate change, and air pollution, increase significantly over time. Furthermore, the spatial effects are significant on ES losses. Losses in an area are not only influenced by continent regions but also by the ALC. Therefore, the majority of the spatial impacts are linked to soil erosion in continental Europe and climate change and air pollution in Asia. Erosion is a major environmental and economic problem that affects all continents, but continental Europe has been particularly affected by soil loss, which has led to land degradation. Ozsahin et al. (2018), for example, found changes that occur in erosion risk in Europe's Maritsa Basin and assessed the potential impacts of the LUC on soil erosion rate. Their findings revealed that the most significant increases in soil erosion were seen in both agricultural and artificial zones, indicating that those two groups are prioritized in soil erosion modeling. In addition, Rodrigo-Comino (2018) explained that agricultural soil erosion was evaluated with a diverse review of studies in European countries. However, the most surveyed countries were France, Italy, Spain, and Greece, and Germany also had a large number of studies. In addition, Chile and Germany were the leading research countries to study primary soil erosion in agriculture. Rodrigo-Comino's investigation revealed that land degradation rates in vineyards were greater than in other land uses, posing a global danger to vineyard sustainability. Furthermore, climate change is presenting a worldwide challenge to sustainable development, particularly in Asian nations located in relatively dry regions in the world. Wen et al. (2017) investigated the spatial variations of temperature and precipitation in northwest China, one of East Asia's driest regions. Their findings showed that the temporal effects of temperature in most meteorological stations, especially in high-altitude stations, were statistically significant. Although the temporal effects in precipitation were not as significant as expected, the spatial effects in precipitation were significant in northwest China.

5.2 The ES losses due to the ALC during the economic development process

Moreover, the findings indicated that all ES losses of the ALC rate have significant coefficients. Increasing the ALC rates leads to an increase in biodiversity losses, CO_2 emission, soil erosion, climate change, air pollution, and water pollution. However, such an increase improves productivity (Table 4). The current study's findings are consistent with those of related research on the ES losses of the ALC (Islam et al., 2015; Marques et al., 2019). In a study, Islam et al. (2015) indicate that the ALC for housing and aquaculture leads to considerable ES losses in Bangladesh. Among those losses are soil salinity and soil erosion in the study area. Converting land into aquaculture capitalist activities requires a lot of financial capital. Thus, individuals who do not have sufficient financial capital for such activities will face environmental losses in the long run. The study results of Tolessa et al. (2017) show that due to LUC from agriculture, several ES with the worth of 3.7 million USD have been lost in Ethiopia during 1973–2015. ES losses include the reduction of nutrients, the reduction of raw materials, and soil erosion. Marques et al. (2019) suggest that the ALC, despite declining economic impacts, led to increased impacts on bird diversity and global carbon sequestration from 2000 to 2011. Biodiversity losses generally take place in Central and South America, Africa, and Asia. Cattle breeding and oilseed farms are mainly recognized as negative and positive factors in biodiversity, respectively. Forestry activities have the greatest influence on carbon sequestration and also have shown the greatest increase in the study period.



Productivity reduction Loss of biodiversity Increase CO_2 Soil erosion



Climate change Air pollution Water pollution

Fig. 8 The test of publication bias for the ES loss of the ALC

Finally, the inappropriate rate of the ALC leads to globally various ecosystem impacts, including loss of biodiversity, CO_2 increase, soil erosion, climate change, air pollution, and water pollution. Therefore, policymakers are advised to prioritize the conservation of agricultural ecosystems in their LUC programs and avoid the rapid conversion of agricultural land. In addition, it is recommended that farmers and consumers of natural ecosystems avoid mechanical soil disturbance to the extent possible, avoid soil compression beyond the soil elasticity, and maintain organic matter during soil rotation until it reaches a level of equilibrium. Furthermore, it is important to use crop residues to conserve soil organic matter and minimize soil erosion by covering crops.

The limitation that the current study has faced is that to date, the evaluation of all ES has not been reported due to the lack of required data and information, lack of effective methods, and various limitations. There is no original study that examines simultaneously all the effects of ES due to the LUC.

6 Conclusion and implications

The review was focused on the rate of ALC and the impact of ALC on ES by using a meta-analysis. The meta-analysis was performed on 43 original papers that identified the ES due to the ALC from 2000 onwards.

The findings of the ES effects indicated that among the temporal effects, significant effects on soil erosion, climate change, and air pollution have been estimated. This means that over time, as agricultural land use has been converted, and soil erosion, climate change, and air pollution have been identified as the greatest consequences. In addition, among the spatial effects, the most impacts on air pollution and climate change have been estimated. In addition, the results of ALC rate coefficients in meta-regression showed that the largest ES losses have been related to soil erosion, and the largest ES gain was related to agricultural productivity. The importance of the findings of the current study is significant, and they can help improve ES by conserving agricultural lands and retaining their use. Improving ES is vital to sustaining human welfare and to future economic and social development. Suitable ecosystems clean our water, refine our air, preserve our land, control the temperature, and provide us with food, raw materials, and supplies for medicines among other things.

According to the findings of this paper, fast agricultural land conversion in the process of economic growth results in a variety of ES losses, including biodiversity loss, increased CO_2, soil erosion, climate change, air pollution, and water pollution. Therefore, it is recommended that the land-use system and the ALC should be modified with careful research programs to reduce the ES losses. Moreover, it is recommended that appropriate land-use plans estimate the value of agricultural land's goods and services. Furthermore, another recommendation is the continuous monitoring of rapid and unauthorized conversion of land use from agriculture to non-agriculture. Finally, it is proposed that the national governments apply fines and levies to unplanned ALC to maintain the balancing of agricultural and non-agricultural lands.

As a policy implication, soil erosion resulting from the fast increase in ALC can lead to economic losses. The economic losses include reduced soil fertility, reduced crop yield, increased water consumption, water pollution, river sediment, waterway closure, declined fish and aquatic species, the inability of the land to retain water, and flooding outbreaks. In addition, lack of attention to the protection of agricultural lands and converting their use led to climate change, which in turn affects the pattern of rainfall, evaporation, and access to water resources. Therefore, policymakers must adopt appropriate policies to protect the soil through proper use of soil resources, soil cover, and runoff control. Furthermore, among the appropriate policies to control climate change is the use of renewable energy sources and tree planting.

Based on the findings, it is recommended that future studies be examined separately to discover methods to reduce ES losses in various regions. Future research can also look into methods to promote economic growth while protecting agricultural areas. It is also possible to investigate how to achieve economic growth while protecting natural resources such as land.

Data availability Data will be made available upon request by the first author.

Declarations

Conflict of interest There is no conflict of interest.

Informed consent All authors have read the manuscript and agreed to its submission.

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